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THESIS

UNITED STATES COMMERCIAL SHIPBUILDING PRODUCTIVITY:
AN INTERNATIONAL VIEW

by

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December 1990

Thesis Advisor Dan C. Boger

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United States Commercial Shipbuilding Productivity: An International View

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis examines American shipyard productivity. An attempt is made to measure changes in U.S. shipbuilding productivity to ascertain if U.S. yards are improving their position relative to their competitors. An international comparison of wages, material and overhead prices and cost structures are used to assess America's current competitive position. This study also provides a qualitative survey of lesser known shipbuilding nations about which little quantitative data has been published. A discussion of obstacles, such as government policy deficiencies and business practices, which continue to inhibit commercial shipbuilding productivity in the United States is also included. Recommendations are also provided.

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I. INTRODUCTION

A. BACKGROUND

For 150 years, the United States commercial shipbuilding industry was regarded as a world leader in innovation, quality, and productivity. Following World War II, however, the industry entered a long decline. Beginning in the 1970's, the productivity of U.S. commercial shipyards was reputed to be only half that of Scandinavian and Japanese shipyards.

During the 1980's, U.S. shipbuilders focused their attention almost exclusively on the construction of a 600 ship Navy to counter their cold war adversary, the Soviet Union. This decade also witnessed Japan's continued domination of world commercial shipbuilding and Korea's emergence as an ever more powerful shipbuilding entity. Other nations honed their shipbuilding prowess and became increasingly fierce competitors in a global commercial market.

The world has changed dramatically as the decade of the 1990's unfolds. For U.S. shipbuilders the focus is shifting away from naval shipbuilding and the cold war and toward industrial competitiveness in commercial markets.

It is against this backdrop, that the issue of U.S. commercial shipbuilding productivity is revisited.

B. PROBLEM STATEMENT

This thesis will attempt to answer several questions about the U.S. commercial shipbuilding industry. These include:

1. Where do U.S. commercial shipbuilders stand with respect to their international competitors?
2. Has U.S. commercial shipbuilding productivity improved during the past decade?
3. What obstacles exist to future productivity gains for U.S. commercial shipbuilders?
4. What actions can be taken to overcome these obstacles?

C. RESEARCH METHODOLOGY

This thesis will examine American shipyard productivity. An attempt will be made to measure changes in U.S. shipbuilding productivity to ascertain if U.S. yards are improving their position relative to their competitors. An international comparison of wages, material and overhead prices and cost structures will be used to assess America's current competitive position. This study will also provide a qualitative survey of lesser known shipbuilding nations about which little quantitative data has been published. A discussion of obstacles in the form of government policy deficiencies and business practices which continue to inhibit commercial shipbuilding productivity will also be included. Recommendations for improving the competitiveness of the industry will also be examined.

Library research and a comprehensive review of international shipbuilding literature provided the vast majority of the information contained in this study. Data provided by the Bureau of Labor Statistics (BLS) will be used to make comparisons about international wages. International trade publications will be used to estimate material prices. Various shipbuilding publications produced by Lloyd and Fairplay will be also used to obtain data on shipbuilding prices and shipbuilding output in foreign countries.

D. CONTENTS OF THE THESIS

The following chapter contains a historical overview of the American shipbuilding industry and statistics relevant to the current status of commercial shipbuilding.

Chapter III describes the methodology which will be used to make a quantitative assessment about labor, material, and overhead productivity in Japan, Europe, and the United States.

Chapter IV will discuss the findings of the quantitative analysis. An in-depth discussion of prevailing international cost structures and the impact which currency exchange rates play in relative comparisons of shipbuilding productivity will also be included.

Chapter V will contain qualitative data gathered about fierce international competition which the U.S. faces. It also will include a discussion of how U.S. government policy and American business practice have been incompatible with the goal of competitiveness in U.S. commercial shipbuilding.

Chapter VI will be comprised of the thesis summary, a conclusion, and recommendations for making the U.S. commercial shipbuilding industry a more competitive entity in the future.

II. BACKGROUND

These are bleak times for United States (U.S.) shipbuilders. During 1989, the U.S. completed 10 commercial ships totalling 4078 gross tons (GT).[1] Put in historical perspective, this production figure represents about three percent of the U.S. shipbuilding output of sailing vessels in the year 1810 [Ref. 2: p. 23]. By contrast, in 1989, Japan produced 640 ships totalling over 5 million gross tons. Comparing U.S. production to Japanese production using an automotive analogy is like saying that while the U.S. produced 10 pick-up trucks in 1989, Japan produced 640 moving vans!

Table 1 on page 4 is a summary of merchant ships completed during 1989 [Ref. 3: p. 3]. If the 54 countries in Table 1 on page 4 had been ranked by GT produced, U.S. shipbuilders would have ranked 36th. The U.S. output is just above Malaysia (2758 GT), Peru (3136 GT) and Chile (3372 GT), but below Greece (5219GT), Czechoslovakia (6172 GT) and Malta (6995 GT) [Ref. 3: p. 3]. The U.S. manufactured three one hundredths of one percent of the world total while Japan produced more than 40 percent of the world's ships.

A particularly disturbing aspect of the abysmal state of U.S. commercial shipbuilding is that at various junctures in the history of this nation, U.S. shipbuilders have excelled in innovative technology and mass production techniques. Indeed, throughout U.S. history, commercial shipbuilding has been an important vehicle for the growth of commerce and a symbol of national vitality. Fast American-built privateers were instrumental in the gaining of U.S. independence from Great Britain and again during the War of 1812. The swift sail-powered clipper ships of the pre-civil war period (1820 to the late 1850's) became the bold and colorful world models for merchant shipping and were valued as much for their ability to outrun pirates as for their fast cargo transit times. These ships permitted the U.S. to be a major player in commerce with Europe, India and the Orient and were an integral part of the development of California after its annexation in 1846.

1 "Gross tonnage is calculated from the total volume of all enclosed spaces of a ship measured in cubic meters using a standard formula" [Ref. 1: p. 387].

Table 1. MERCHANT SHIPS COMPLETED DURING 1989

Rank	Where Built	No.	Gross Tonnage	Percentage of World Tonnage
1	JAPAN	640	5,364,600	40.53
2	KOREA(SOUTH)	102	3,101,568	23.43.
3	YUGOSLAVIA	26	496,716	3.77
4	GERMAN,FEDERAL REPUBLIC OF	54	430,845	3.26
5	CHINA, REPUBLIC OF TAIWAN OF	9	404,892	3.06
6	DENMARK	33	342,960	2.59
7	ITALY	35	327,565	2.47
8	CHINA, PEOPLE'S REPUBLIC OF	20	325,719	2.46
9	ROMANIA	17	307,331	2.32
10	GERMAN DEMOCRATIC REPUBLIC	33	287,185	2.17
11	SPAIN	130	230,906	1.74
12	POLAND	44	199,391	1.51
13	FINLAND	21	193,970	1.47
14	U.S.S.R.	59	174,277	1.32
15	BRAZIL	11	164,885	1.25
16	FRANCE	27	159,565	1.21
17	UNITED KINGDOM	35	102,393	0.77
18	ARGENTINA	11	89,759	0.88:
19	NETHERLANDS	53	88,814	0.67
20	INDIA	17	80,349	0.61
21	BULGARIA	10	76,603	0.58
22	BELGIUM	2	39,438	0.30
23	MEXICO	2	37,873	0.29
24	CANADA	13	32,980	0.25
25	NORWAY	35	32,710	0.25
26	SINGAPORE	25	23,638	0.18

Table 1. MERCHANT SHIPS COMPLETED DURING 1989, CONTINUED

Rank	Where Built	No.	Gross Tonnage	Percentage of World Tonnage
27	PORTUGAL	16	21,430	0.16
28	TURKEY	13	14,783	0.11
29	EGYPT	2	13,300	0.10
30	SWEDEN	14	12,963	0.10
31	INDONESIA	3	8,300	0.06
32	AUSTRALIA	30	7,304	0.06:
33	MALTA	4	6,995	0.05
34	CZECHOSLOVAKIA	2	6,172	0.05
35	GREECE	4	5,219	0.04
36	**UNITED STATES**	**10**	**4,078**	**0.03**
37	CHILE	8	3,372	0.03
38	PERU	7	3,136	0.02
39	MALAYSIA	2	2,758	0.02
40	THAILAND	2	2,600	0.10
41	BANGLADESH	5	1,168	0.01
42	HUNGARY	4	1,092	0.01
43	SURINAM	1	700	0.01
44	HONG KONG	3	528	0.00
45	ISRAEL	1	492	0.00
46	SRI LANKA	1	440	0.00
47	IRAN	1	200	0.00
48	UNITED ARAB EMIRATES	1	194	0.00
49	ICELAND	1	143	0.00
50	BRUNEI	1	115	0.00
51	AUSTRIA	..	..	0.00
52	COLOMBIA	..	..	0.00
53	NEW ZEALAND	..	..	0.00
54	VENEZUELA	..	..	0.00

In more modern times, the Liberty and Victory ships built just before and during World War II were essential elements in the U.S. emerging victorious during this crisis. It is remarkable even by today's standards that during 1945 alone U.S. shipyards completed 1067 vessels totalling 7,663,362 gross tons [Ref. 2: pp. 14-16, 267]. Even during their period of decline since World War II, U.S. designers developed the architecture for many of the ships currently plying the world's oceans. The cellular containership, Roll-On, Roll Off (RO-RO) ship, Lighter Aboard Ship (LASH) barge carrier and Liquid Natural Gas (LNG) carrier are all American developments [Ref. 2: p. 28].

Today, even U.S. shipowners buy their ships abroad. The 1990 World Orderbook reveals that U.S. shipowners rank fifth in the world in total deadweight[2] tons (DWT) being purchased as shown in Table 2 [Ref. 4: pp. i-xv, pp. vi and xii].

Table 2. THE WORLD'S TOP FIVE SHIP BUYING NATIONS IN DWT

Nation	Number of Vessels Being Purchased	DWT
Japan	260	11,938,371
Norway	158	8,233,459
Sweden	61	5,153,000
Denmark	105	3,817,568
United States	60	2,870,440

Of this total, less than 12 percent of ships being purchased by U.S. owners will be U.S. built as shown in Table 3 on page 7.

Of the 2,870,440 DWTs being built for U.S. owners, 822,827 will be U.S. flag vessels. The balance will fly the colors of other countries. Virtually all of these ships will be "flags of convenience". It is instructive to look at the U.S. flag portion of these ships being purchased and the country of build as shown in Table 4 on page 7 and Table 5 on page 7.

Note that almost 60 percent of the U.S. flag ships being built will be built by foreign yards. Ironically, despite their recent dismal performance in the commercial sector, U.S.

2 Deadweight is the measurement of the total weight of cargo that a vessel can carry when it is loaded down to its marks. This includes the weight of fuel, stores, water ballast, fresh water, passengers and baggage [Ref. 1: p. 387].

Table 3. TOTAL SHIPS BEING BUILT FOR U.S. SHIPOWNERS BY SOURCE

Country of Build	Number of Ships	Percentage of DWT	DWT
Ships being built in U.S. yards	11	11.54	331,337
Ships being built in foreign yards	49	88.46	2,539,213
Total ships in DWT being purchased by U.S. owners	60	100	2,870,440

Table 4. U.S. FLAG VESSELS ON ORDER 1990

Number of Ships	Owner/Operator	DWT/ Ship	Total DWT	Country of Build	Type
3	Chevron	150,000	450,000	Brazil	Crude oil carrier
2	Transoceanic Cable	7,900	15,800	Singapore	Cable ship
2	Chiquita Brands	12,900	25,800	Japan	Part refrigerator container
2	ODECO	Not listed	N/A	South Korea/U.S.	Semi-submersible oil ring
10	U.S. Navy	30,412	304,120	U.S. (Avondale)	product tanker
1	Matson Navigation	27,107	27,107	U.S.(Natl Steel)	container liner
20	Total Ships	--	822,827	Total DWT	--

Table 5. U.S. FLAG VESSELS BEING BUILT BY SOURCE

Number of Ships	Source of Build	DWT	Percent
9	Foreign built	491,600	59.75%
11	US Built	331,227	40.25%
20	Total DWT	822,827	100%

shipbuilders are the unquestioned world leaders in the construction of technologically sophisticated naval warships. Two examples follow:

1. As a rule, the more technologically complex the vessel, the more competitive is the U.S. shipyard. In fact there is probably only one shipyard in the entire world capable of building a nuclear-powered aircraft carrier--much less the three simultaneously under construction at the Newport News Shipbuilding and Drydock Company in the mid 1980's [Ref. 2: p. 104].
2. In the case of the AEGIS ship (U.S. Navy Guided Missile Cruiser) that Japan is going to be building for itself, they are building a smaller destroyer than we are currently building and it is going to cost them almost $300 million more to build than what the larger version can be built for in the United States [Ref. 5: p. 47].

A puzzled observer might reasonably query why an industry that is currently capable of commercial and military innovation and that has demonstrated periodically throughout its history a remarkable resiliency in time of crisis has fallen on such hard times. The current plight of American shipyards is the result of a host of factors. One principal factor has been the historic lack of a comprehensive commercial maritime policy which has led to bitter division and parochialism among the principal players in the maritime arena (shipowners, shipbuilders, Navy, administration, Congress, and various labor interests). The product of this lack of unified policy has been shipyards that have failed to increase their productivity during periods of substantial government subsidy. The implementation of a recent piece of important maritime legislation, the Merchant Marine Act of 1970, is a case in point:

> The government pledged to support a 300 ship 10 year subsidized program, where the goals are a 45 percent Construction Differential Subsidy (CDS)[3] in fiscal year 1971 with a reduction in the ceiling of 2 percentage points a year until a level of 35 percent was reached in fiscal year 1976. After a propitious start in the early 1970's when CDS rates did fall to the 35% goal, rates began to rise again. By the early 1980's, a rate closer to 65 to 70 percent would have been required to match international shipbuilding prices. By early 1982, the CDS portion of the 1970 Act was abandoned altogether. The telling impact of U.S. shipbuilder's failure to improve productivity was that only 80 of the planned 300 ships were ever built [Ref. 6: pp. 154-156].

The hindsight of a 1990 perspective reveals that the inability to improve productivity in the late 1970's and early 1980's led, in this author's opinion, to the justified suspension

[3] CDS is a direct subsidy paid to U.S. shipyards building U.S. flag ships to offset high construction costs in American shipyards. An amount of subsidy (up to 50 percent) is determined by estimates of construction cost differentials between U.S. and foreign yards [Ref. 6: p. 222].

of CDS in 1982. This sent the commercial sector of the U.S. shipbuilding industry into a tailspin from which it may never recover.

The lesson is clear. Any future program which hopes to revitalize the U.S. commercial shipbuilding industry must focus on the factors of production. A viable program must underscore the importance of competitive labor rates and skill levels; affordable material costs, the American cost of capital, the process of production, the competencies and long range planning abilities of our political leaders, and the management abilities of our shipyard executives.

This thesis will focus on the factors of production, labor, material and capital, for the U.S. shipbuilding industry. It will provide a comparative analysis of the status of U.S. shipbuilders with respect to their foreign competitors. It is important to realize that the issue is not simply one of buying commercial ships from foreign countries who can produce them more cheaply. The reduction in the number of commercial ships built in the U.S., while irksome and wounding to national pride, is not disastrous in peacetime. The concurrent erosion of a military shipbuilding industrial base in a deficit-hobbled nation, in which an unwary majority believe this nation will never again require the use of force, could prove injurious to national security. Even if times are indeed to be relatively peaceful in the post-cold war world (and recent experience in the Middle East indicates they will not be), then America ought to utilize and improve upon its shipyard base to restore its economic vitality and husband its shipyards as valuable industrial assets for an uncertain and potentially hazardous future.

Simply stated, the U.S. needs to target productivity improvements in commercial shipbuilding to preserve the shipbuilding industrial base in an era when military budgets are shrinking. The bottom line issue which must be addressed is why "it costs twice as much and takes twice as long to build a commercial ship in a U.S. shipyard as a comparable ship" in a modern foreign shipyard [Ref. 6: p. 109].

III. METHODOLOGY

This thesis will historically compare the factors of production (labor, materials, and overhead) among the world's shipbuilders. Shipbuilding costs in Europe and Asia will be compared with U.S. costs from the early 1980's to the present time. An effort will be made to assess the relative competitiveness of the U.S. shipbuilding industry with respect to these factors of production.

A. U.S. COMPETITIVENESS: 1990 DEFINITION

As can be surmised from the information in the previous chapter, the U.S. commercial shipbuilding industry will not in the foreseeable future capture any significant portion of the world market. Indeed, this is not a new phenomenon. The U.S. has not exported a commercial ship since 1957 [Ref. 7: p. 18], and the heyday of World War II vintage Liberty and Victory ships is now no more than a historical curiosity.

The U.S. will almost certainly play no role in what some observers forecast to be a global newbuilding boom in the 1990's [Ref. 8: p. 1]. Competitiveness for U.S. commercial shipbuilders in the 1990's might be defined as:

- Recapturing contracts for aging U.S flag vessels from foreign shipbuilders for U.S. ships engaged in international trade
- Being cost effective enough to forestall repeal by Congress of existing legislation which mandates that U.S. ships engaged in the U.S. coastal trades be built in U.S. yards
- Being productive enough to survive as an industry which, if again subsidized, could provide both a decent living for those engaged in the industry and the U.S. taxpayer a reasonably good value for his dollar.

It should perhaps be emphasized at this point that while free trade is certainly a noble goal in the global shipbuilding arena, virtually all world shipbuilders, except those in the U.S., are subsidized in some manner. Put differently, if the U.S. government's sole objective were to obtain quality, low cost commercial ships to replace the aging U.S. flag fleet and if protectionist legislation were not a barrier, the U.S. commercial shipbuilding industry would cease to exist.

Having placed reasonable, short term competitive goals for the U.S. shipbuilder into sharper focus, it is appropriate to discuss the methodology entailed in the historical analysis of the recent past with respect to the individual costs of production: labor, material cost, and overhead. After a discussion of the source for each individual factor the underlying assumptions and mechanics of their weighted combination will be explained.

B. SOURCE DATA

1. Labor

Hourly compensation costs for production workers in the Ship and Boat Building and Repairing Industry were obtained from the Division of Foreign Labor Statistics, Office of Productivity and Technology within the U.S. Bureau of Labor Statistics [Ref. 9: pp. 1-3]. This data includes hourly wages in U.S. dollars and in the respective foreign currency for 13 representative shipbuilding nations. Nations included are the U.S., Japan, South Korea, Belgium, Denmark, Finland, France, West Germany, Italy, the Netherlands, Norway. Spain, and the United Kingdom. This report provides yearly data on each country for the period 1981 through 1989. A comparative index is also contained (using U.S. as 100 for each year) for ready analysis. Appendix A contains the labor data used in this study.

2. Material

For the purpose of this study, steel was gauged to be the principal material element in shipbuilding. International steel prices for heavy plate steel were obtained from yearly editions of the Metal Bulletin Handbook and its successor, Metal Bulletin's Prices and Data Book [Ref. 10 pp. 157-241 and Ref. 11 pp. 183-240]. The germane unit of measurement used was the metric ton. Since the periodicity of published market prices varied greatly from country to country, a weighted yearly average price by country converted to U.S. dollars per metric ton was used in this study. Prices in foreign currencies were converted into U.S. dollar using tables provided by the Bureau of Labc Statistics [Ref. 12: pp. 10 and 18]. A currency conversion table is provided for the period 1981 through 1989 in Appendix B.

It should be noted here that the international steel industry is certainly not without its eccentricities. The thickness of heavy plate is defined differently at various times in different countries. It is sometimes quoted separately from medium plate and at other times together with medium plate. If quoted separately, heavy plate prices were used. If heavy plate prices varied on the basis of minor differences in quality, steel making process, or Free on Board (FOB) pricing between differing plants, then a weighted average was taken to accommodate the variation. No effort was made to calculate discounts offered on the basis of quantity purchased. Treaty of Paris prices for

"Structural and Shipbuilding Plate" were used in the case of the United Kingdom. Appendix C contains data gathered for the period on steel prices.

Korean steel prices, while unavailable in the Metal Bulletin [Ref. 10: pp. 157-241 and Ref. 11: pp.183-240] were taken from Jenks and Larner [Ref. 13: p.16] and Carson and Lamb [Ref. 7: p. 7]. for specific years and used to make qualitative comments about material costs in that nations's shipbuilding industry in Chapter V.

Heavy plate steel prices were not available for Norway. In order to include this country in the study, Swedish heavy plate prices, converted to dollars with a nominal charge attached for import transportation, were used for Norway.

Heavy plate prices for Spain were not available for the period 1981 through 1985. Prices for 1981 through 1985 were obtained by comparing the relationship of Spanish steel prices during 1986 through 1989 to other European prices and projecting that trend back through 1981.

3. Overhead

The sum of fixed and variable overhead was considered to be that portion of cost which could not be directly related to labor or material. These numbers were extracted from the four cost structure models detailed in Section C below. Fixed overhead was considered to be comprised of "allotments for the replacement of facilities and repayment of borrowed capital and working capital" [Ref. 13: p. 20]. A principal determinant of fixed overhead was considered to be the cost of capital prevalent in the nations of various major shipbuilders. Variable overhead was considered to consist of costs such as "light, heat and power related to production, insurance, drydock charges, management and administrative expense, data processing expense, sales expense and yard maintenance and security" [Ref. 13: p.20]. It is significant to note that indirect burden costs for yard labor, i.e., fringe benefits for production workers, are included under this category. This is, however, consistent with the manner in which these figures are reported by the Bureau of Labor Statistics (who exclude benefits from hourly wage comparisons) as well as the studies by Jenks and Larner [Ref. 13 pp. 1-20], and Jenks and Landsburg [Ref. 14 pp. 44-66], and Carson and Lamb [Ref. 7: pp. 1-32] which are used extensively in this paper.

C. THE MODEL

In order to gain insight into the relative productivity of the world's shipbuilders during the period under consideration, (1981 through 1989), one must understand three things:

1. The cost structures prevalent in different nations
2. The general trend of newbuilding (new commercial construction) prices during the period
3. The relationship of Japanese prices to costs.

1. The Cost Structures

Four studies, Jenks and Larner (1982), [Ref. 13: pp. 1-20], Jenks and Landsburg (1988) [Ref. 14: pp. 44-66], Porter and Cho (1985) [Ref. 15: pp. 539-567], and Carson and Lamb (1990) [Ref. 7: pp. 1-32], are used extensively to conveniently segment the nine year period into two distinct periods: the steady fall of newbuilding prices from 1981 to a trough in 1985 and the rapid rise of prices from 1985 through 1989.

The 1982 Jenks and Larner study [Ref. 13: pp. 1-20] is based on cost structures prevalent in 1981 in Japan, Northern Europe, and the U.S. It provides a useful starting point for the decade of the 1980's. It focuses on the relative ship construction costs for building a 90,000 DWT tanker.

The 1988 Jenks and Landsburg [Ref. 14: pp. 44-66] study is a continuation of Jenks work from 1982 covering the period 1981 though 1985. It focuses on the major tanker builders of that era, Japan and Korea. This study was used as a basis for establishing Japanese cost and pricing relationships in 1985. Porter and Cho's [Ref. 15: pp. 539-567] work centers on global marketing strategies in shipbuilding. However, useful cost comparisons found in this study enabled the author to draw conclusions about relative cost structures between Japan and Northern Europe at the midpoint of the nine year period covered in this thesis.

The 1990 Carson and Lamb study [Ref. 7: pp. 1-32] formats cost structures in a fashion similar to the original Jenk's study [Ref. 13: pp. 1-20]. It defines and segments the total cost structure into the same principal categories as do the other studies. It includes cost percentages reputed to exist for labor, material, and overhead in the U.S. and compares these to percentages prevalent in Japan and Northern Europe. It does not reference cost structures relative to a specific ship type, but pertains to relative shipbuilding cost structures in general. The relationships of these four studies are shown in Table 6 on page 14.

In order to draw conclusions about productivity in different nations on the basis of relative cost structures, the information derived from the four studies is considered to be valid for shipbuilding construction cost structures in general. The methodology of this thesis will be to align and knit these four studies together in order to obtain an

Table 6. COMPARISON OF FOUR SHIPBUILDING COST STRUCTURE STUDIES

Study	Period Covered	Newbuilding Prices	Year Written
Jenks & Larner	1981	High	1982
Jenks & Landsburg	1981-1985	Low	1988
Porter & Cho	1985	Low	1986
Carson & Lamb	1989	High	1990

overall picture of productivity in different nations. The melding of the four studies is shown in Table 7 on page 15. The U.S. is considered as 100 percent for each of the three periods depicted in the table. Two examples for interpreting Table 7 on page 15 follow:

1. In 1981, Japanese shipbuilding costs were 45.4 percent of U.S. costs
2. In 1989, Northern European shipbuilding costs were 96 percent of U.S. costs

Some additional explanatory notes are necessary. The 1982 Jenks study [Ref. 13: pp. 1-20] was used in conjunction with the Carson and Lamb study [Ref. 7: pp. 1-32] to obtain costs structures for the U.S. during the 1985 period.

One cautionary note about the Carson and Lamb study [Ref. 7: pp. 1-32] should be made at this point. While the relative percentages allocated to the major costs categories (labor, material, and overhead) were not considered to be unreasonable, those allocated to fixed and variable overhead did seem surprising as shown in Table 8 on page 16. For example, if taken at face value, Japanese fixed overhead costs rose by a factor of eight, from 2 in 1985 as estimated by Jenks and Landsburg in Table 7 to 16 in 1989 as estimated by Carson and Lamb in Table 8 on page 16. Similarly, Northern European overhead costs rose by a factor of ten, from 1.9 in 1985 to 20 in 1989. (Compare Table 7 on page 15, Models 2 and 3, to Table 8 on page 16). For this reason, the percentages allocated for fixed and variable overhead were reversed within each country in Table 7, i.e., the 9 percent allocated to fixed overhead in Table 7 on page 15 for Japan in 1989 was Carson and Lamb's estimate of variable overhead for Japan shown in Table 8 on page 16. The 10 percent allocated to Northern European in Table 7 on page 15 in 1989 for fixed overhead was Carson and Lamb's estimate of var-

Table 7. FOUR COST STRUCTURE MODELS: A CHRONOLOGICAL COMPARISON OF RELATIVE WORLD SHIPBUILDING COSTS

MODEL 1: 1981 JENKS and LARNER			
COST COMPONENT	**JAPAN**	**EUROPE**	**U.S.**
Labor	7.3	10.6	20.6
Material	28.6	32.0	42.8
Fixed Overhead	2.3	3.2	16.6
Variable Overhead	7.2	10.2	20.0
Total	45.4	56.00	100.0
MODELS 2 and 3: 1985 JENKS and LANDSBURG, 1985 PORTER and CHO			
COST COMPONENT	**JAPAN**	**EUROPE**	**U.S.**
Labor	13.3	16.0	22.3
Material	16.3	18.1	41.4
Fixed Overhead	2.0	1.9	14.3
Variable Overhead	6.2	6.2	22
Total	37.8	42.2	100.0
MODEL 4: 1989 CARSON and LAMB (with Revised Overhead Estimates)			
COST COMPONENT	**JAPAN**	**EUROPE**	**U.S.**
Labor	16	30	24
Material	34	36	40
Fixed Overhead	9	10	12
Variable Overhead	16	20	24
Total	75	96	100

iable overhead in Table 8 on page 16. This author feels justified in performing this reversal for three reasons:

1. The knowledge that Japanese shipbuilders are currently operating very close to 100% capacity and it seems unreasonable to conclude that greater utilization of existing plant and equipment with minimal slack would cause skyrocketing expenditures on fixed cost [Ref. 16: p. 378]
2. The U.S. data for estimating commercial ships is based on five orders since 1982
3. The reversed numbers seem to fit the historical pattern much more closely.

Table 9 on page 17 converts the numbers from Table 7 into individual cost structures by region. Table 10 on page 18, Table 11 on page 18, and Table 12 on page

Table 8. CARSON AND LAMB COST STRUCTURE ESTIMATES FOR 1989

Cost Component	Japan	Europe	U.S.
Labor	16	30	24
Material	34	36	40
Fixed Overhead	16	20	24
Variable Overhead	9	10	12
Total	75	96	100

19 reconstruct the intervening years 1982, 1983, 1984, 1986, 1987, and 1988 in a linear fashion to include for Japan (Table 10) and Europe (Table 11) the impact on cost structures of the newbuilding price plunge from 1981 to 1985 and the sharp rise from 1985 to 1989. Using these four studies as points of references, the impact on cost structure of a decrease in prices from 1981, the starting point of the nine year period. until 1985 (the midpoint of the period) was assumed to occur on a constant basis; i.e., for Japan the increase of six index points in the labor index from 7.3 in 1981 to 13.3 in 1985 as show in Tables 7 and 10 was assumed to occur at the rate of 1.5 index points per year or 6 index points over four years. The rise in labor of 2.7 index points from 13.3 in 1985 to 16 in 1989 (the nine year endpoint), shown in Tables 7 and 10, was assumed to occur at the rate of 2.7/4 or .675 index points per year. (Numbers are rounded in Tables 10, 11 and 12, to ease further computations). In Table 11 for the U.S., a single linear trend from 1981 to 1989 was selected for two reasons:

1. Very few commercial ships were built during this period and consequently the data, if it were available would be very sketchy.
2. When construction differential subsidies were suspended in 1982, it is fairly safe to assume that U.S. shipbuilders were in no relative position to drastically alter their cost structure to vie for market share when newbuilding prices bottomed out in 1985.

Cost structures in Tables 10, 11 and 12 have been left in terms relative to one another to facilitate analysis.

2. Newbuilding Prices

Newbuilding prices experienced dramatic change from 1981 to 1989. Prices for newbuilding of all types reached their highest levels since the previous peak in 1974 during 1981. Prices declined steadily during 1982, 1983, and 19 bottoming out in

Table 9. COST STRUCTURES BY PERCENTAGE IN LOCAL TERMS: 1981-1989

MODEL 1: 1981 JENKS and LARNER			
COST COMPONENT	JAPAN	EUROPE	U.S.
Labor	16.1	18.9	20.6
Material	63.0	57.2	42.8
Fixed Overhead	5.1	5.7	16.6
Variable Overhead	15.8	18.2	20.0
Total	100	100	100
MODELS 2 and 3: 1985 JENKS and LANDSBURG, 1985 PORTER and CHO			
COST COMPONENT	JAPAN	EUROPE	U.S.
Labor	35.2	37.9	22.3
Material	43.1	42.9	41.4
Fixed Overhead	5.3	4.5	14.3
Variable Overhead	16.4	14.7	22.0
Total	100	100	100
MODEL 4: 1989 CARSON and LAMB (with Revised Overhead Estimates)			
COST COMPONENT	JAPAN	EUROPE	U.S.
Labor	21.3	31.3	24
Material	45.4	37.5	40
Fixed Overhead	12.0	10.4	12
Variable Overhead	21.3	20.8	24
Total	100	100	100

1985. During 1986, 1987, 1988, and 1989 prices climbed steeply. In 1989 newbuilding prices were more than double the level achieved during 1985 and surpassed those of the previous high experienced during 1981. Most experts have explained this rise in prices as caused by a rash of newbuilding activity associated with replacement shipping for tonnage built during the boom period of the early 1980's [Ref. 17: pp. 1-2 and Ref. 18: p. 49]. During the latter part of the 1970's and the mid 1980's when newbuilding prices were low and competitors slashed prices to maintain market share, the global response was to reduce shipbuilding capacity by closing underutilized yards [Ref. 19: p. 47]. The

Table 10. JAPANESE RELATIVE COST STRUCTURE: 1981-1989

YEAR	LABOR	MATE-RIAL	FIXED OVER-HEAD	VARI-ABLE OVER-HEAD	TOTAL
1981	7.3	28.6	2.3	7.2	45.4
1982	8.8	25.5	2.2	7.0	43.5
1983	10.3	22.6	2.2	6.8	41.9
1984	11.8	19.4	2.1	6.5	39.8
1985	13.3	16.3	2.0	6.2	37.8
1986	14.0	20.7	3.8	8.7	47.2
1987	14.7	25.2	5.5	11.1	56.5
1988	15.3	29.6	7.3	13.6	65.8
1989	16.0	34.0	9.0	16.0	75.0

Table 11. NORTHERN EUROPEAN RELATIVE COST STRUCTURE: 1981-1989

YEAR	LABOR	MATE-RIAL	FIXED OVER-HEAD	VARI-ABLE OVER-HEAD	TOTAL
1981	10.6	32.0	3.2	10.2	56.0
1982	12.0	28.5	2.9	9.2	52.6
1983	13.3	25.1	2.6	8.2	49.2
1984	14.7	21.6	2.2	7.2	45.7
1985	16.0	18.1	1.9	6.2	42.0
1986	19.5	22.6	3.9	9.7	55.7
1987	23.0	27.1	6.0	13.1	69.2
1988	26.5	31.5	8.0	16.6	82.6
1989	30	36	10	20	96

surge in prices after 1985 reflects both the demand for new tonnage and reduced capacity for building.

Table 12. U.S. RELATIVE COST STRUCTURE: 1981-1989

YEAR	LABOR	MATE-RIAL	FIXED OVER-HEAD	VARI-ABLE OVER-HEAD	TOTAL
1981	20.6	42.8	16.6	20.0	100.00
1982	21.0	42.5	16.0	20.5	100.00
1983	21.4	42.1	15.5	21.0	100.00
1984	21.8	41.8	14.9	21.5	100.00
1985	22.3	41.4	14.3	22.0	100.00
1986	22.7	41.1	13.7	22.5	100.00
1987	23.1	40.7	13.2	23.0	100.00
1988	23.5	40.4	12.6	23.5	100.00
1989	24.0	40.0	12	24	100.00

Figure 1 reflects newbuilding price trends during the period 1981 through 1989. This graph was constructed by taking a composite weighted average of deadweight tonnage ordered in the world during this period [Ref. 19: p. 61 and Ref. 20: pp. 684-687]. Tonnage was divided into two types, tankers of four different classes and four different classes of bulk and combined carriers. Weights were assigned on the basis of total tonnage in the world orderbook. Appendix D contains the details.

The graph reflects the change in preference from bulk and combined carriage tonnage from 1981 through 1986 to tanker tonnage during 1987, 1988, and 1989. Appendix D contains the Minitab output used to obtain composite newbuilding prices.

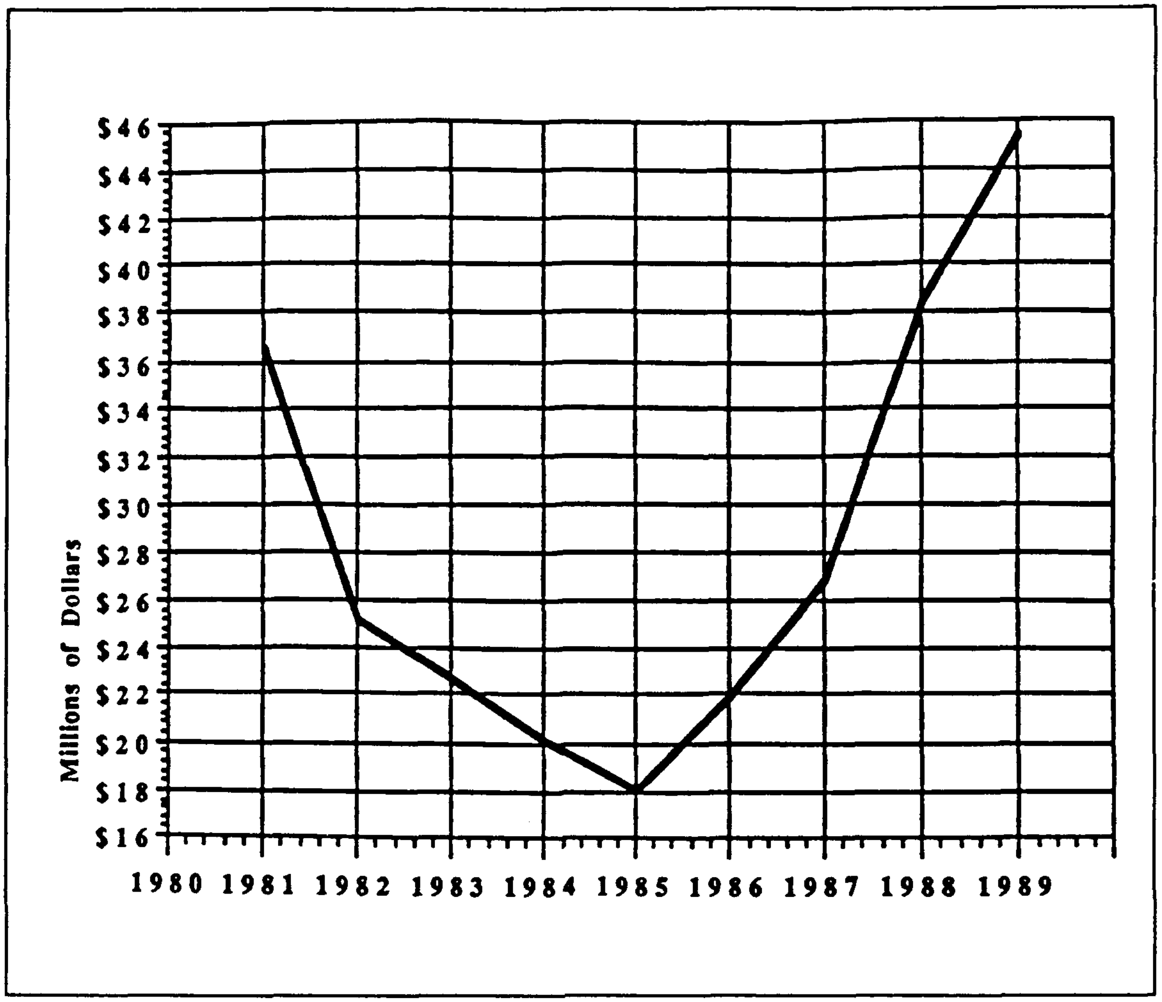

Figure 1. Composite Newbuilding Prices (1981-1989)

3. Japanese Price/Cost Relationship

Japanese shipbuilders dominated the world during the 1980's, manufacturing better than 40 percent of the world's new shipping during the decade [Ref. 21: p. 5]. However, impressive as this nation's performance has been in the shipbuilding arena, its commanding market position has not been achieved painlessly.

Faced with Korean competition whose hourly labor rates were one-third of Japan's throughout much of the decade, Japan was forced to slash prices to maintain market share [Ref. 14: p.45].

On the basis of Jenks and Larner's 1982 study [Ref. 13: p. 132]; its extension, the 1988 Jenks and Landsburg work [Ref. 14: p. 46]; and other shipbuilding literature [Ref. 22: p. 132], after a breakeven year in 1981, the shipbuilding industry in Japan continues to accumulate losses and is not expected to turn a profit until 1991. As Table 13 indicates, shipbuilding prices have not covered total shipbuilding cost since 1981.

Table 13. JAPANESE COST/PRICE RELATIONSHIPS: 1981-1989

YEAR	Percentage of Total Cost Covered by Price
1981	100
1982	88.75
1983	77.5
1984	66.25
1985	55
1986	62.5
1987	70
1988	77.25
1989	84.5
1990 (Projected)	91.75
1991 (Projected)	100

D. PRODUCTIVITY MEASUREMENT

In order to draw quantitative conclusions about productivity in different nations, it is necessary to convert relative cost and price structures into a common currency and extract measures of relative productivity such as manhours expended per ship and metric tons of steel used per ship.

Table 14 on page 22 converts composite newbuilding prices (CNP) (in millions of dollars) provided in Figure 1 into total cost by area. This is accomplished by converting total relative costs from Tables 10, 11 and 12 into the coefficients shown in columns (2), (5) and (7) of Table 14. On the basis of their manufacturing dominance, Japan was chosen as the building block for Northern European and U.S. cost structures. For example, in the year 1981, the Japanese cost coefficient (JCC) is 45.4/45.4 or 1, the Northern European cost coefficient (NECC) is 56/45.4 or 1.23 and the U.S. cost coefficient (USCC) is 100/45.4 or 2.2. Column 3 of Table 14 models Japan's price setting dominance in the shipbuilding marketplace [Ref. 15: p. 558]. In other words, the Japanese relationship between cost and price is the method used to convert the composite newbuilding prices to newbuilding costs in each of the three areas. Since Japan priced below cost during much of the nine year period, the Japanese price coefficients (JPC) in this column are the reciprocals of those listed in Table 13 on page 21.

Table 14. COMPOSITE NEWBUILDING COSTS BY AREA: 1981-1989

YR	CNP	JCC	JPC	JSC	NECC	NESC	USCC	USSC
--	Col(1)	Col(2)	Col(3)	Col(4)	Col(5)	Col(6)	Col(7)	Col(8)
81	36.592	1	1.0	$36.592	1.23	$45.136	2.20	$80.599
82	25.084	1	1.13	$28.264	1.21	$34.177	2.30	$64.974
83	22.615	1	1.29	$29.189	1.17	$34.264	2.39	$69.643
84	20.027	1	1.51	$30.230	1.15	$34.711	2.51	$75.954
85	17.965	1	1.82	$32.664	1.11	$36.294	2.65	$86.414
86	21.824	1	1.60	$34.918	1.18	$41.206	2.12	$73.979
87	26.804	1	1.43	$38.291	1.22	$46.898	1.77	$67.772
88	38.377	1	1.29	$49.679	1.26	$62.363	1.52	$75.500
89	45.277	1	1.18	$53.582	1.28	$68.585	1.33	$71.443

Columns (4) Japanese ship cost (JSC), (6) Northern European ship cost (NESC), and (8) U.S. ship cost (USSC) in Table 14 reflect the newbuilding cost for the composite ship type by year for each of the respective areas. Table 15 on page 23, Table 16 on page 23, and Table 17 on page 24 convert the data provided in Table 10 on page 18, Table 11 on page 18, and Table 12 on page 19 from relative percentages to local percentages of cost for Japan, Northern Europe and the U.S. For example, in Japan during 1981, labor represented 7.3/45.4 of the total cost or 16.1 percent.

Table 15. LOCAL COST PERCENTAGES FOR JAPANESE SHIPBUILDERS

YEAR	LABOR	MATE-RIAL	FIXED OVER-HEAD	VARI-ABLE OVER-HEAD	TOTAL
Col(1)	Col(2)	Col(3)	Col(4)	Col(5)	Col(6)
1981	16.1	63.0	5.1	15.8	100
1982	20.9	58.0	5.15	15.95	100
1983	25.7	53.0	5.2	16.1	100
1984	30.4	48.1	5.25	16.25	100
1985	35.2	43.1	5.3	16.4	100
1986	31.7	43.7	7.0	17.6	100
1987	28.2	44.2	8.7	18.9	100
1988	24.8	44.8	10.3	20.1	100
1989	21.3	45.4	12.0	21.3	100

Table 16. LOCAL COST PERCENTAGES FOR NORTHERN EUROPEAN SHIPBUILDERS

YEAR	LABOR	MATE-RIAL	FIXED OVER-HEAD	VARI-ABLE OVER-HEAD	TOTAL
Col(1)	Col(2)	Col(3)	Col(4)	Col(5)	Col(6)
1981	18.9	57.2	5.7	18.2	100
1982	23.7	53.6	5.4	17.3	100
1983	28.4	50.0	5.1	16.5	100
1984	33.1	46.5	4.8	15.6	100
1985	37.9	42.9	4.5	14.7	100
1986	36.3	41.6	6.0	16.1	100
1987	34.6	40.2	7.4	17.8	100
1988	33.0	38.9	8.9	19.2	100
1989	31.3	37.5	10.4	20.8	100

Table 17. LOCAL COST PERCENTAGES FOR U.S. SHIPBUILDERS

YEAR	LABOR	MATE-RIAL	FIXED OVER-HEAD	VARI-ABLE OVER-HEAD	TOTAL
Col(1)	Col(2)	Col(3)	Col(4)	Col(5)	Col(6)
1981	20.6	42.8	16.6	20	100
1982	21.0	42.5	16.0	20.5	100
1983	21.5	42.1	15.4	21	100
1984	21.9	41.8	14.8	21.5	100
1985	22.3	41.4	14.3	22	100
1986	22.7	41.1	13.7	22.5	100
1987	23.2	40.7	13.1	23	100
1988	23.6	40.4	12.5	23.5	100
1989	24.0	40	12	24	100

1. Labor Productivity

Labor productivity can be extracted from the composite ship cost (CSC) data by year and country using *Equation (3.1) to solve* for manhours (MHRS) per ship. Equation (3.1) defines the basic relationship of wages (\$/MHR) and manhours per ship (MHRS/SHIP) to the percentage of the composite ship cost (CSC) which is labor.

$$(\$/MHRS) \times (MHRS/SHIP) = (\%\ LABOR) \times CSC \tag{3.1}$$

Equation (3.2) converts this relationship to data described in Appendix A (wages per hour by country), Tables 15, 16 and 17 (Col 2) (percentage of cost which is labor in each respective area: Japan, Northern Europe, and the U.S.), and Table 14 (Col 4, 6 or 8) which is the ship costs in each respective area. The symbol (x) is used to represent the unknown measure of labor productivity (MHRS/SHIP).

$$(\textit{Appendix A wages}) \times (x) = \textit{Table}\ 15{,}16, \text{ or } 17\,(\textit{Col}\,2\,) \times \textit{Table}\ 14(\textit{Col}\,4, 6, \text{ or } 8) \tag{3.2}$$

Equation (3.3) indicates that a solution for the unknown measure of labor productivity (x), MHRS/SHIP can be obtained by dividing the right hand side of equation (3.2) by Appendix A (wages per hour by country).

$$x \;=\; (MHRS/SHIP) \;=\; Table\ 15{,}16 \text{ or } 17\ (Col\ 2) \times \frac{Table\ 14\ (Col\ 4,\ 6 \text{ or } 8)}{[Appendix\ A\ wages]} \quad (3.3)$$

2. Material Productivity

Material productivity can be extracted from the composite ship cost data by year and by country using equation (3.4) to solve for metric tons of steel (MTS). Equation (3.4) defines the basic relationship of steel price (\$/MTS) and metric tons of steel used per ship (MTS/SHIP) to the percentage of composite ship cost (CSC) which is material.

$$\$/MTS \times MTS/SHIP \;=\; (\%\ MATL) \times\ CSC \qquad (3.4)$$

Equation (3.5) converts this relationship to data described in Appendix C (steel price by country), Tables 15, 16, and 17 (Col 3) (percentage of cost which is material in each respective area: Japan, Northern Europe, and the U.S.) and Table 14 (Col 4, 6, or 8)) which is the ship cost in each respective area. The symbol (y) is used to represent the unknown measure of material productivity (MTS/SHIP).

$$(Appendix\ C\ price) \times\ (y) \;=\; Table\ 15{,}16, \text{ or } 17\ (Col\ 3) \times Table\ 14\ (Col\ 4,\ 6 \text{ or } 8\ ) \quad (3.5)$$

Equation (3.6) indicates that a solution for the unknown measurement of material productivity (y), (MTS/SHIP) can be obtained by dividing the right hand side of equation (3.5) by Appendix C (steel price per metric ton by country).

$$y \;=\; (MTS/SHIP) \;=\; Table\ 15{,}16, \text{ or } 17(Col\ 3\ ) \times \frac{Table\ 14\ (Col\ 4{,}6 \text{ or } 8\ )}{[Appendix\ C\ price]} \quad (3.6)$$

The number of metric tons of steel used per ship is being utilized to be representative of the units of raw and finished material used in ship construction. Propulsion equipment, pipe, instrumentation for the bridge and engine room, various pumps, generators, electrical equipment, air conditioning equipment and a host of other machinery are required in constructing a ship. Detailed historical cost accounting methods and accurate information on ship suppliers throughout the globe would be necessary to correctly apportion and quantify unit costs for these items. Clearly, such an effort is beyond the scope of this thesis. It is hoped that relative productivity comparisons based on steel will be helpful in assessing a given country's efficiency in material use during ship construction.

3. Overhead Productivity

Quantified comparative measurement of overhead productivity by country will not be attempted in this thesis. Useful information pertinent to fixed overhead on the cost of capital in Japan, the U.S., West Germany and Great Britain will be provided later in this work. Other qualitative information on variable overhead will be provided as available for comparison of countries' variable overhead costs.

Regrettably, there is no simple unit of measurement such as hourly wage rate or steel price per metric ton for extracting a unit of overhead productivity from the composite ship cost.

4. Country Selection

The following countries have been selected for inclusion in this study based primarily on the available data and their level of proficiency in ship production:

- Japan
- Belgium
- Denmark
- Finland
- France
- West Germany
- Italy
- The Netherlands
- Norway
- Spain
- United Kingdom
- United States

It is unfortunate that a more comprehensive effort could not have been performed for South Korea, the world's second largest shipbuilder. If data for cost structures had been available, a complete analysis similar to that used for Japan, Northern Europe and the U.S. would have been conducted.

Italy, Spain and the United Kingdom, while not considered Northern European shipbuilders have been included for two reasons:

1. Each has a rather considerable shipbuilding capability
2. They provide a source of contrast with other European nations.

These countries will be classified in the following chapter as Southern European shipbuilders.

Important shipbuilding nations such as Peoples' Republic of China, Brazil, Yugoslavia, and other former eastern block countries have been excluded from the quantitative portion of the study due to a lack of data on cost structure and unavailability of steel prices. However, qualitative comments on these nations and their importance in the world shipbuilding scene will be made later in this study.

IV. DATA ANALYSIS

A. GENERAL OVERVIEW

This chapter will cover two major topic areas. It will first explain the significance of the differences between the cost structures in Japan, Europe and the United States. For each area the individual components of cost: labor, material and overhead (both fixed and variable) will be discussed. The impact of changes in wages and material prices to the local cost structure composition will be addressed. Since the focus of this study is the U.S. shipbuilding industry, an effort will be made to draw attention to the relevant impact of differing foreign cost structures as they relate to the structure which exists in the U.S. Second, the results of the productivity study will be presented. An effort will be made to highlight the driving factors in the historical differences in labor and material productivity among the nations within the context of the methodology discussed in Chapter III.

B. COST STRUCTURE

The cost structures extracted from the four studies display contrasting shipbuilding industries in the respective areas. The Japanese and Northern European cost structures underwent significant change during the nine year period. The U.S. cost structure remained remarkably stable. Differences in wages and prices in the respective countries drove changes to the cost structures. However, the effect of currency changes played a significant role throughout the decade in the relative differences in shipbuilding costs.

1. Japan

Labor costs as a percentage of total costs in local terms more than doubled from slightly greater than 16 percent in 1981 to more than 35 percent in 1985, but dropped back to around 21 percent by 1989. Japanese shipbuilders reduced the percentage in local terms of costs expended on material by nearly 18 percent from 63 percent in 1981 to 45.4 percent in 1989. Overhead costs grew during the 1980's by nearly 21 percent. Overall, Japanese relative costs increased from 45.5 percent of U.S. cost in 1984 to 75 percent of U.S. cost in 1989 although much of this increase could be attributed to the weakened value of the dollar against the yen.

a. Japanese Labor Costs

The rise in wages in yen from 1981 until 1985 accounted for most of the sharp rise in the percentage of costs expended on labor between 1981 and 1985. Figure

2 displays two line graphs. The upper graph represents the percentage of total cost in local terms expended on labor. The lower graph represents the hourly earnings in yen for Japanese shipyard workers. Note that from 1981 until 1987, labor cost percentages and wages move in the same direction. Only during 1988 and 1989 do wages in yen and labor cost percentages move in different directions. The seeming anomaly of 1988 is a reflection of Japanese shipbuilders' attempts to lure back workers laid off during the newbuilding price slump of the mid 1980's.

> With strong demand in the steel and construction industry for skilled labor and a bad image shipbuilders got for allegedly behaving selfishly in sacking their employees recruitment is difficult. And wages in the steel industry are double those of shipyard workers [Ref. 22 p. 133].

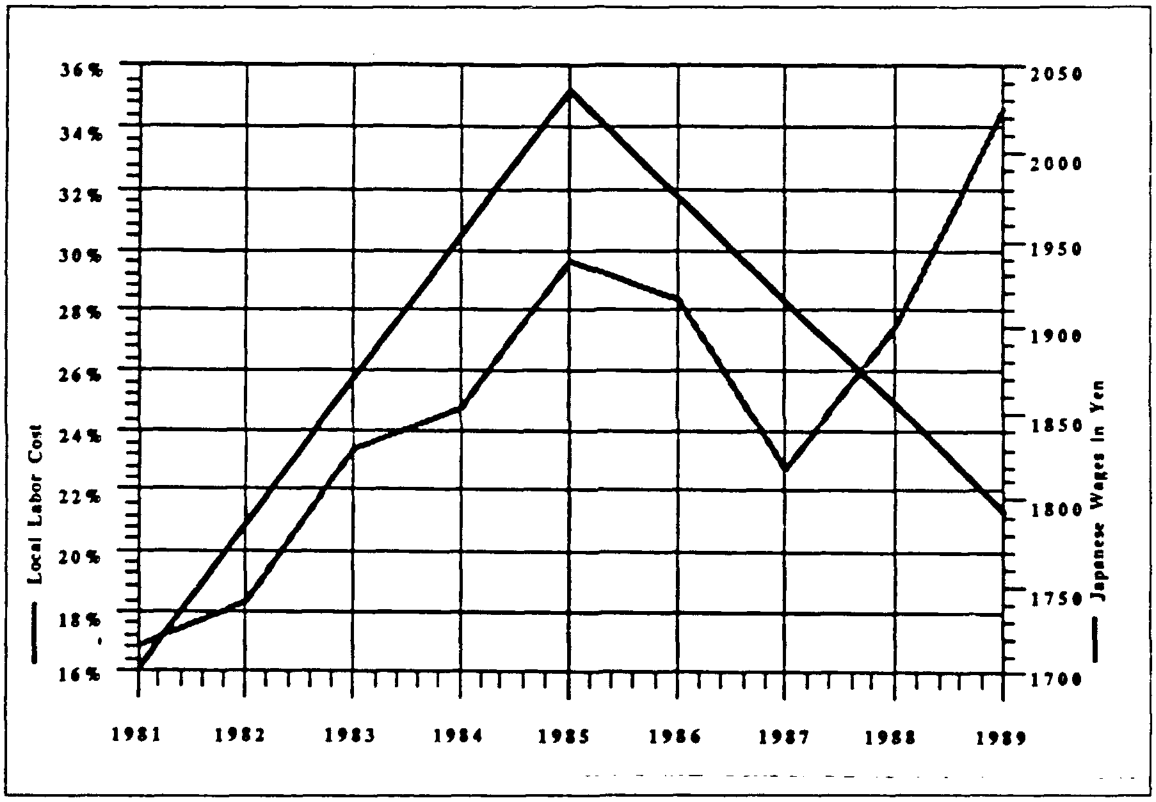

Figure 2. Japanese Labor Cost vs Japanese Wages (1981-1989)

It is also significant to note that if the trend of rising wage increases continues, it could have the impact of pushing both labor cost and overall costs upward.

Also of interest is the fact that Japanese shipyard workers in 1989 earned $14.67 per hour compared to U.S. workers who earned $14.77 an hour. This contrasts sharply with the relationship that existed between the two nations in the not so distant past and debunks the notion that Japan gained competitive advantage on the basis of inexpensive labor. Table 18 on page 30 summarizes the changes in Japanese wages in dollars per hour ($/hr) [Ref. 9: p. 3].

Table 18. JAPANESE AND U.S. SHIPYAPD PRODUCTION WORKER WAGES IN $/HR

Countries	1975	1980	1985	1988	1989
U.S.	6.84	11.22	14.57	14.33	14.77
Japan	3.92	6.75	8.12	14.83	14.67

b. Japanese Material Costs

Local material costs as a percentage of the total dropped markedly during the first half of the decade and rose only marginally from 1985 through 1989. Figure 3 displays two line graphs. One line represents local material costs as a percentage of the total cost. The other line of the graph, displays the prices of metric tons of steel in yen during the period.

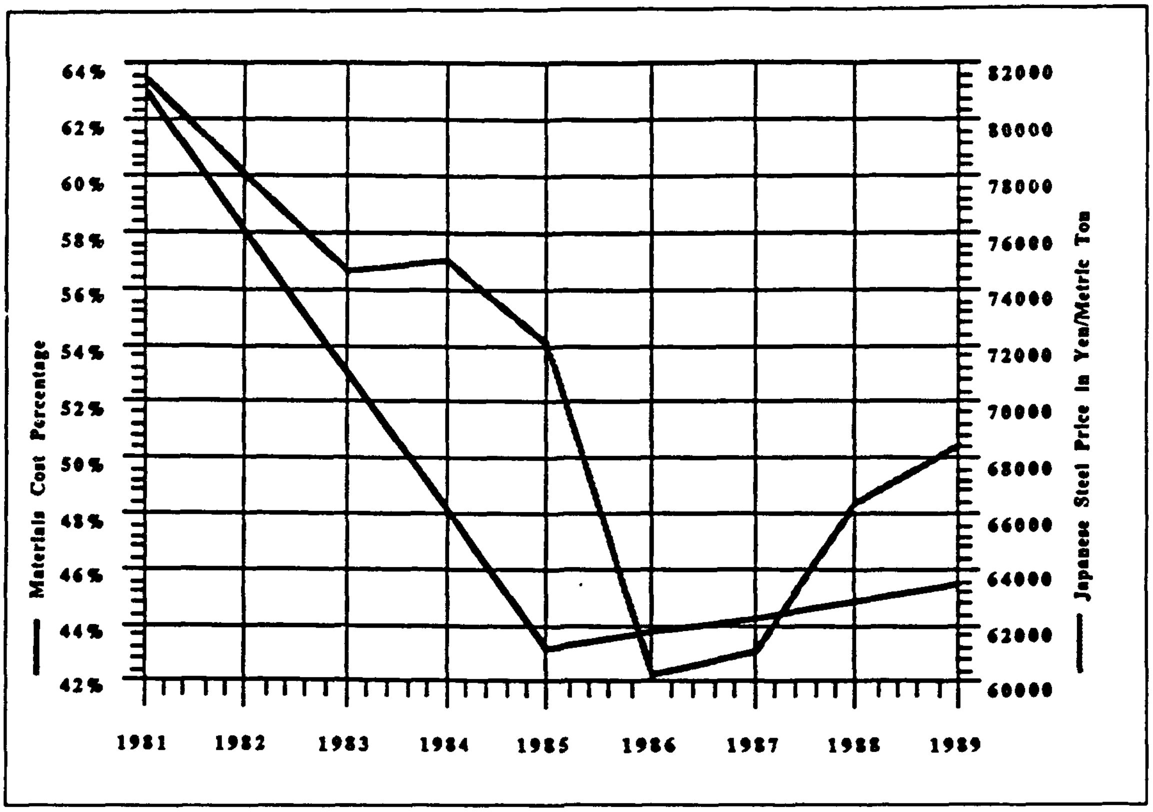

Figure 3. Local Japanese Material Cost vs Steel Prices in Yen (1981-1989)

It is interesting to contrast the currency conversion effect on material prices during the period. Figure 4 shows the currency impact on the relative cost structure. Note that by converting yen to dollars, the sharp downturn of steel prices in yen, shown in Figure 3, from 1981 through 1985 appears relatively flat when measured in dollars, and the sharp dip in price from 1985 to 1986 measured in yen actually translates to a $70 increase in dollar price during this period. The modest rise from 60,119 yen in 1986 to 68,498 yen in 1989 as shown in Figure 3, appears dramatic when measured in dollars in Figure 4.

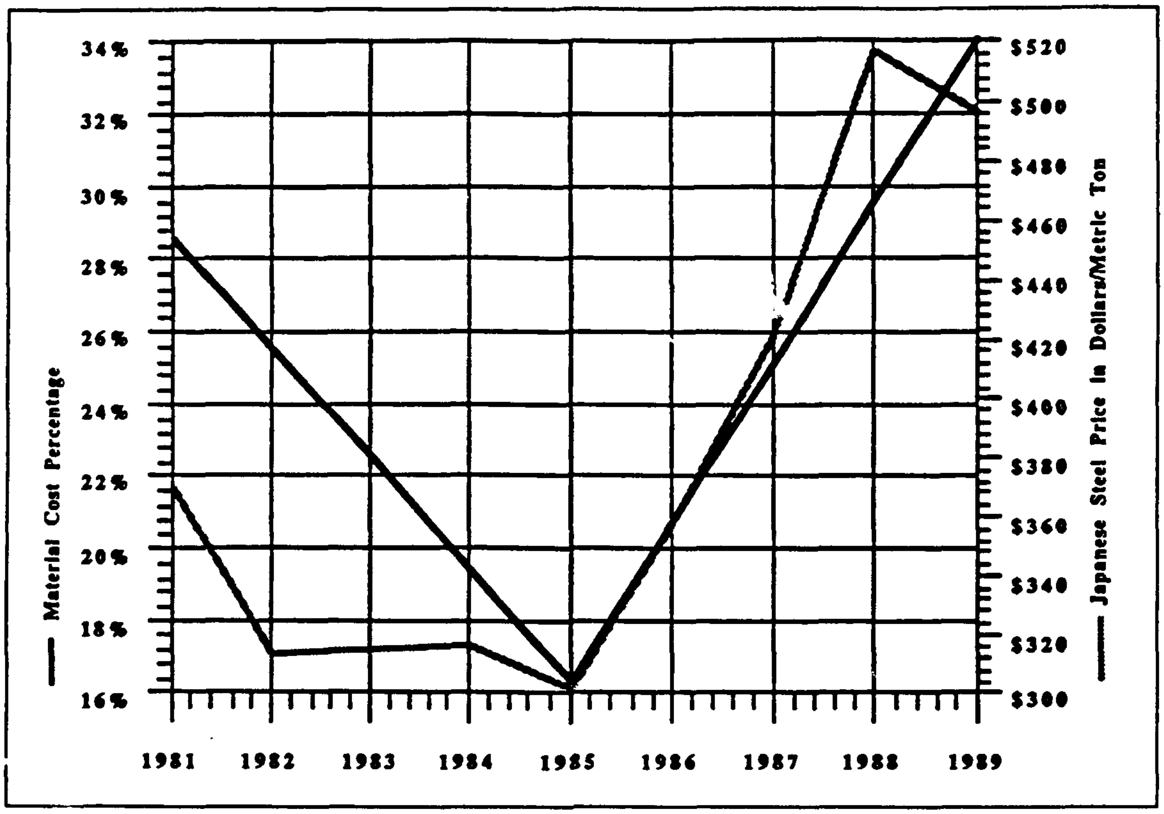

Figure 4. Relative Japanese Material Cost vs Steel Price in Dollars (1981-1989)

In summary, material costs showed a marked decline in yen during most of the nine year period. However, in relative terms because of a weakening dollar which declined from 225 yen in 1981 to 138 yen in 1989, the relative percentage of shipbuilding cost allocated to material grew from 28.6 to 34 index points.

c. Japanese Overhead Costs

Japanese overhead costs remained remarkably constant in local and relative terms throughout the early part of the decade, but climbed sharply in the latter part of the decade. However, despite the rise in the percentage of total cost allocated to overhead, Japan still enjoys a significant advantage over its competitors with respect to relative overhead costs. The advantage in fixed overhead cost results from a number of factors which are discussed in the following paragraphs.

Japan experienced tremendous production throughput using existing capacity. From 1981 to 1989, Japan produced an amazing 63,581,412 gross tons (GT) of shipping. Table 19 on page 33 contrasts Japanese production to U.S. production during the entire decade of the 1980's [Ref. 3: p. 3, Ref. 23: pp. 76-77, Ref. 24: pp. 28-60, Ref. 25: pp. 1-2, and Ref. 26: pp. 1-2]. The amount of throughput in tons produced translated into very efficient use of plant, equipment and machinery resources since the high volume of production lowered the fixed costs per unit.

Table 19. JAPANESE PRODUCTION VS U.S. PRODUCTION IN GT OF COMMERICIAL SHIPS DURING THE PERIOD 1981-1989

Year	Japan	United States
1981	8,399,831	360,136
1982	8,162,915	215,746
1983	6,670,317	380,899
1984	8,972,974	146,702
1985	8,763,957	117,679
1986	7,498,721	132,659
1987	5,707,898	164,326
1988	4,040,199	10,765
1989	5,364,600	4,078

Learning curve and experience curve effects were more fully realized because of the quantity and diversity of ships produced. Large orders for families of sister ships meant reduced fixed costs per ship. One area where the effects of mass production on fixed overhead costs are most pronounced was in the fabrication of engineering drawings. Ishikawajima Harma Heavy Industries Company Ltd. "IHI", a leading Japanese shipbuilder, employs a technique called, "Module Design", to minimize design cost.

> That is, if parts of ships are similar, design modules from the previous history are adapted as is or with some improvement. It is important not to waste energy and resources by treating every new design as if there were no precedent. Data accumulated from previous designs are the company's valuable property. Retrieval of and combining this data have proved to be effective by using the computer-aided design system, CAD [Ref. 27: p. 110].

In essence, this entails minimal design costs since old designs are readily accessed by computer. Clearly, such a database also provides the supplemental benefit of making it easier to bid on new ship construction projects. Successful techniques indeed appear to breed further triumphs.

Japan enjoyed a relatively low cost of capital. The cost of capital is defined as the rate of interest corporations pay on loans used to finance investment in new machinery and equipment. A relatively low rate of interest tends to spark investment in more modern equipment and machinery which can be used to boost productivity. Higher rates of interest tends to discourage investment in new productivity enhancing technology. Table 20 displays the cost of capital in Japan and the United States from 1981 though 1988 for equipment and machinery with a physical life of 20 years. Table 20 also shows the gap between the two nations [Ref. 28: p. 16].

Table 20. COST OF CAPITAL (1981-1988) FOR EQUIPMENT AND MACHINERY WITH A LIFE OF 20 YEARS IN U.S. AND JAPAN

Year	U.S.	Japan	Gap
1981	13.5	8.8	4.7
1982	11.5	8.5	3.0
1983	10.6	8.8	1.8
1984	11.3	8.4	2.9
1985	11.1	8.3	3.2
1986	9.1	7.8	1.3
1987	10.2	7.0	3.2
1988	11.2	7.2	4.0

Japanese shipbuilders also enjoyed a competitive advantage in variable overhead costs with respect to U.S. shipyards. One explanation for this advantage is the more costly medical benefits accrued by U.S. workers. Medical benefits are included as an indirect cost and as such are usually allocated to variable overhead cost in proportion to direct labor manhours. According to Carson and Lamb [Ref. 7: pp. 8-9] there exists a $3.40 per manhour advantage for health care costs in a Japanese yard compared to a U.S. yard.

2. Northern Europe

Labor costs in Northern Europe rose significantly in local terms from 1981 to 1989. The rise was precipitous from 1981 to 1985 moving from 18.9 percent in 1981 to 37.9 percent in 1985, but dropping back to 31.3 percent in 1989. Material costs shrunk from a high of 57.2 percent in 1981 to a low of 37.5 percent in 1989. Overhead costs grew by 7.3 percent from 23.9 percent in 1981 to 31.2 percent in 1989. Overall relative

European cost ballooned from 56 percent of U.S. cost to 96 percent of U.S. cost in the 1980's.

a. Northern European Labor Costs

Northern European wages outstripped those in Japan, the U.S. and Southern Europe during the 1980's. By 1989, West German shipyard workers had become the highest paid in the world, earning $20.16 per hour. They were followed closely by Finland at $19.66 per hour, Norway at $19.63 per hour, and Denmark at $16.23 per hour. By contrast Japanese workers earned $14.67 per hour and U.S. workers earned $14.77 per hour in 1989. Other European shipyard workers gained wage increases during the 1980's, but earned less that their Northern European counterparts. In 1988, Spanish workers earned $10.85 per hour while in 1989, British workers earned $10.06 per hour. Figure 5 is indicative of the role wages played in shaping the local and relative labor cost structure present in Northern Europe. The uppermost line graph illustrates the pattern of labor cost in local percentage. The middle graph shows wages in deutschemarks throughout the 1980's and the lower graph indicates the changes over time of the relative Northern European cost structure. The fact that wages in deutschemarks continued to increase, while the local percentage of labor cost declined, is indicative of the fact that increases in local overhead percentages outstripped even wage gains after 1985 as a contributor to higher overall Northern European ship costs.

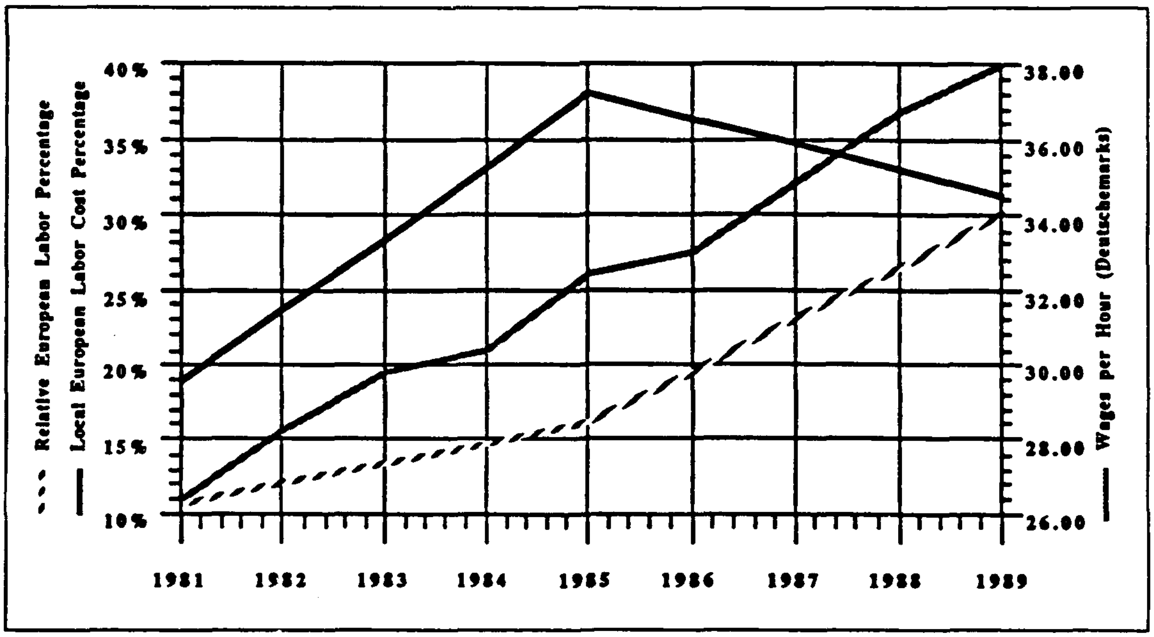

Figure 5. European Local and Relative Labor Cost vs Wages in Deutschemark (1981-1989)

b. Northern European Material Costs

Local material costs as a percentage of the total dropped throughout the decade. Relative material costs declined from 1981 to 1985 and rose from 1985 to 1989. Figure 6 depicts local material cost plotted against steel prices in French francs, Danish krone, and Finnish markha. It would seem that rising steel prices were less important than the increases in local labor and overhead percentages in shaping the declining direction of the percentage of cost allocated to material.

Figure 7 shows French, Finnish, and Danish steel prices plotted in U.S. dollars versus relative material cost percentages. The shapes of the three European curves bear remarkable similarity and seem to correspond reasonably well to the Northern European relative cost. It is significant to note that currency exchange effects between these three European countries and the U.S. occur in the same direction and are primarily responsible for the drastic differences in the appearances between Figure 6 and Figure 7.

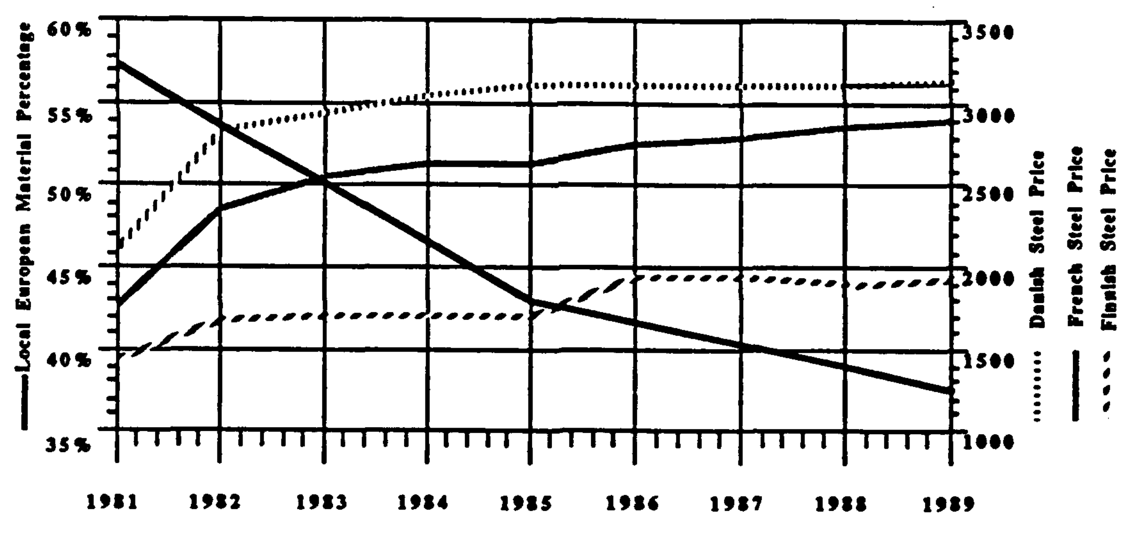

Figure 6. Local European Material Cost vs Steel Prices in Various European Currencies (1981-1989)

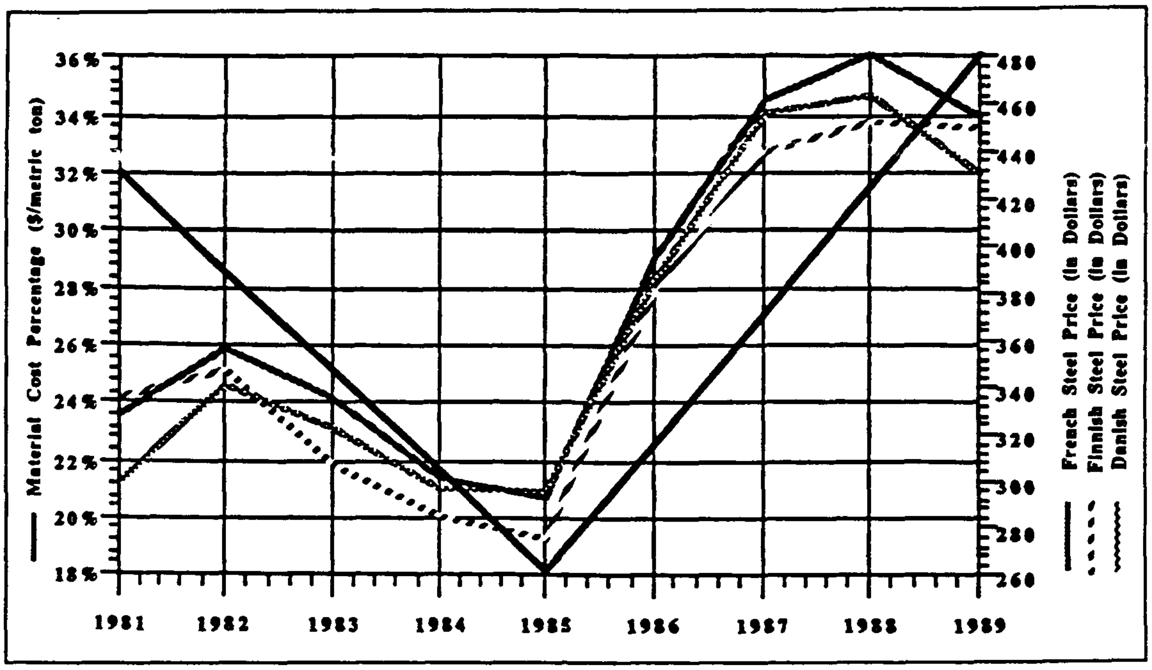

Figure 7. **Northern European Steel Prices in Dollars vs Relative Material Cost (1981-1989)**

Figure 8 plots the currency exchange rates of the Danish krone, French franc and Finnish markha against the U.S. dollar. By contrasting Figure 7 to Figure 8, it is apparent that a stronger dollar drove dollar-denominated European steel prices lower during the earlier part of the decade and a weaker dollar drove dollar-denominated steel prices upward in the latter part of the decade.

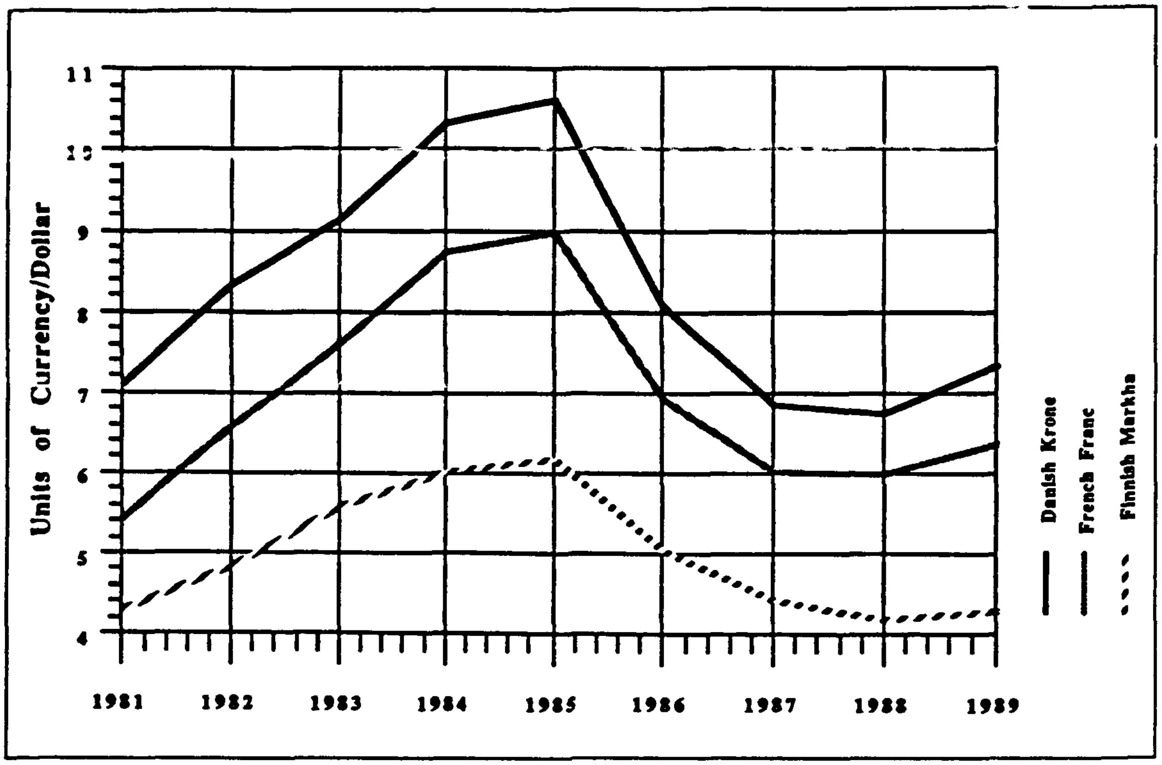

Figure 8. Exchange Rates of Three European Currencies per Dollar (1981-1989)

c. Northern European Overhead Costs

Northern European overhead costs in local and relative terms declined modestly from 1981 until 1985, but climbed dramatically during the latter part of the decade. In relative terms Northern European shipbuilders enjoyed a significant advantage over U.S. builders but lagged behind Japan.

A significant advantage enjoyed by European builders over their American counterparts with respect to fixed overhead exists in the area of cost of capital. Table 21 on page 39 details capital cost in the U.S., United Kingdom, and West Germany for equipment and machinery with a physical life of 20 years [Ref. 28: p. 16].

Lower capital costs gave European shipbuilders a greater incentive to borrow money to finance more modern plant and equipment. European shipbuilders did not enjoy the fixed cost advantage of several million gross ton throughput experienced by Japanese shipbuilders during the 1980's. In fact, by virtue of their higher relative total ship cost, particularly during the era of declining new building prices in the early 1980's, some European builders' output was rocked to a small fraction of a more pro-

Table 21. COST OF CAPITAL (1981-1988) FOR EQUIPMENT AND MACHINERY WITH A LIFE OF 20 YEARS IN U.S., U.K. AND WEST GERMANY

Year	U.S.	United Kingdom	West Germany
1981	13.5	10.3	8.8
1982	11.5	10.7	7.8
1983	10.5	10.8	7.0
1984	11.3	9.3	7.2
1985	11.1	9.4	7.1
1986	9.1	7.8	6.9
1987	10.2	8.2	7.0
1988	11.2	9.2	7.0

ductive past. Table 22 on page 39 illustrates this phenomenon [Ref. 3: p. 3, Ref. 23: pp. 76-77, Ref. 24: pp. 28-60, Ref. 25: pp. 1-2, and Ref. 26: pp. 1-2].

Table 22. GROSS TONS PRODUCED BY THREE NORTHERN EUROPEAN COUNTRIES (1981-1989)

Year	Belgium	Netherlands	Norway
1981	223,021	172,964	310,164
1982	260,416	212,186	347,463
1983	118,183	231,758	182,036
1984	178,138	134,265	93,081
1985	124,506	72,707	78,704
1986	99,176	193,363	88,315
1987	14,336	59,300	62,264
1988	54,767	59,232	52,589
1989	39,438	88,814	32,710

While not all European shipbuilders suffered to the extent depicted in Table 22, most lost significant gross tonnage during the 1980's. (Appendix E contains total ship production output in GT for all twelve countries listed in the quantitative portion of this study. Korean output is also included.) As a consequence, the economies of scale inherent in large operations were responsible for the higher fixed and variable overhead figures seen in Europe during the late 1980's.

It is interesting to note that despite the higher wages earned in Northern Europe, U.S. shipyard workers still accrue more costly medical benefits. These benefits appear as an indirect cost charged against variable overhead. Carson and Lamb [Ref. 7: pp. 8-9] estimate that the advantage of less costly medical benefits for German shipyard workers amount to $2.55 per direct labor hour over U.S. shipyard workers.

3. United States

Labor cost rose moderately in the U.S. during the 1980's. Material costs declined 2.8 percent form 42.8 percent to 40 percent and total overhead costs as a percentage of total costs remained roughly the same throughout the decade. A decline of 4.6 percent in fixed overhead costs was offset by a rise of 4.0 percent in variable overhead costs. While no segment of the overall cost structure displayed dramatic change during the 1980's, the vast differences in total cost evident between Japan and Europe during 1981 shown in Table 7 on page 15 had diminished greatly by 1989.

Figure 9 displays the impact of yen to dollar currency conversion during the 1980's with respect to the total cost structure of U.S. and Japanese shipbuilders. It is perhaps not surprising that when the yen to dollar ratio is high (as occurred during the period 1981 through 1985) that Japanese costs are relatively low when compared to U.S. costs and that, consequently, when the yen to dollar ratio was low (as occurred from 1986 through 1989) that Japanese costs grew relative to U.S. costs.

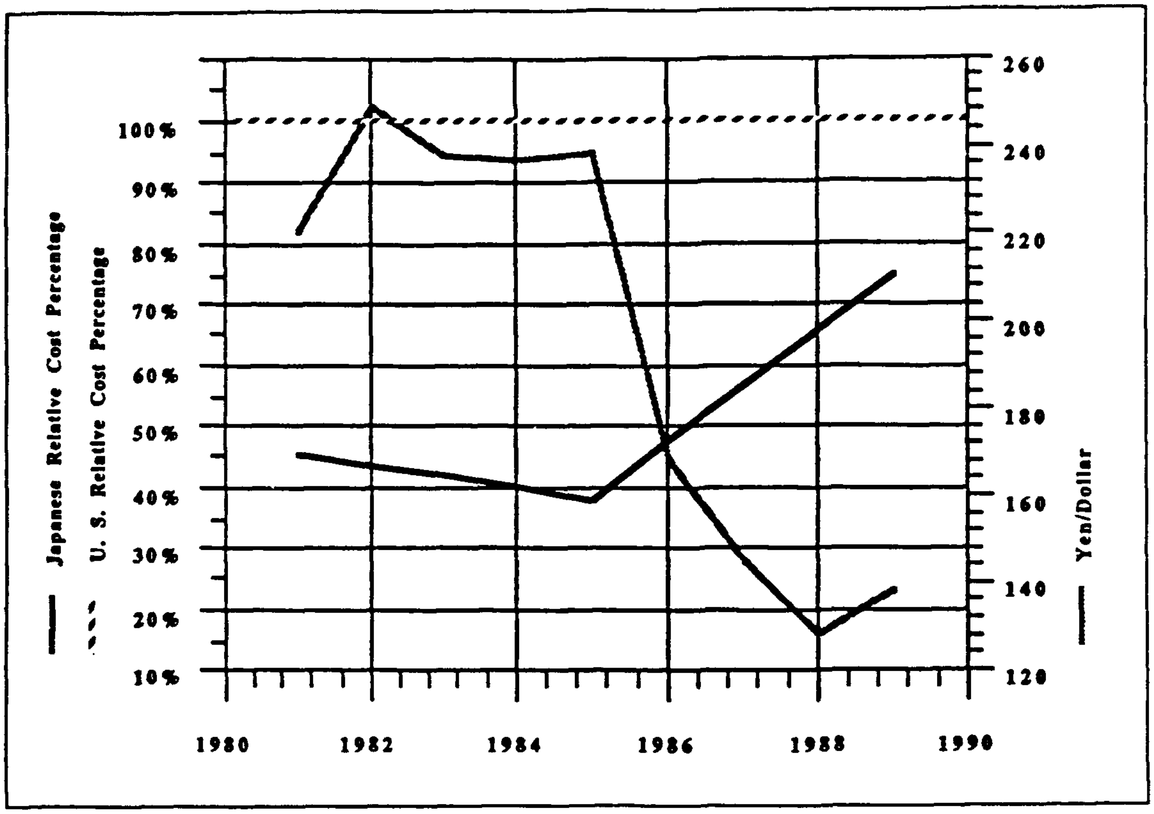

Figure 9. Relative Cost Structures in U.S. and Japan vs Number of Yen per Dollar (1981-1989)

Figure 10 illustrates the impact of deutschemark-to-dollar currency conversion during the 1980's in relation to the total cost structure of U.S. and Northern European shipbuilders. Northern European costs are low relative to U.S. costs when the deutschemark-to-dollar ratio is high and Northern Europe costs grow relative to U.S. costs when the deutschemark to dollar ratio is low. Therefore, it is illusory to presume that because the gap between Japanese and Northern European shipbuilders and U.S. shipbuilders has narrowed that U.S. shipbuilders are necessarily becoming more cost efficient. Much of the reduced relative cost gap can be explained by currency conversion effects.

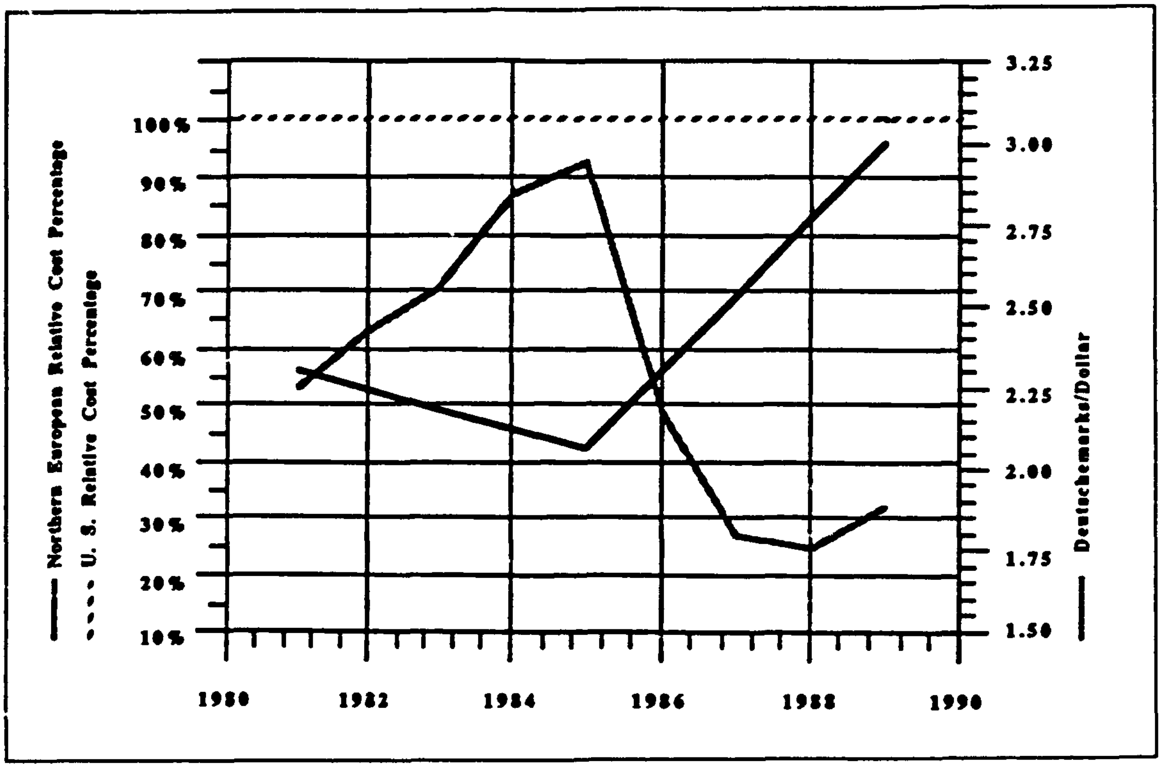

Figure 10. Relative Cost Structures in U.S. and Northern Europe vs Deutschemark per Dollar (1981-1989)

a. U.S. Labor Costs

Most of the rise in U.S. labor costs can be explained by wages which rose from $12.29 per hour in 1981 to a high of $14.77 per hour in 1989. Wages fell slightly from 1986 until 1988 when they reached a level of $14.33 per hour. Figure 11 illustrates the relationship between labor cost and wages. While U.S. workers currently earn less than their Japanese and Northern European counterparts, it is interesting to note that U.S. wages were more than twice as high as those of the world's second largest shipbuilder, Korea. Korean shipyard workers in 1989 earned only $6.35 per hour.

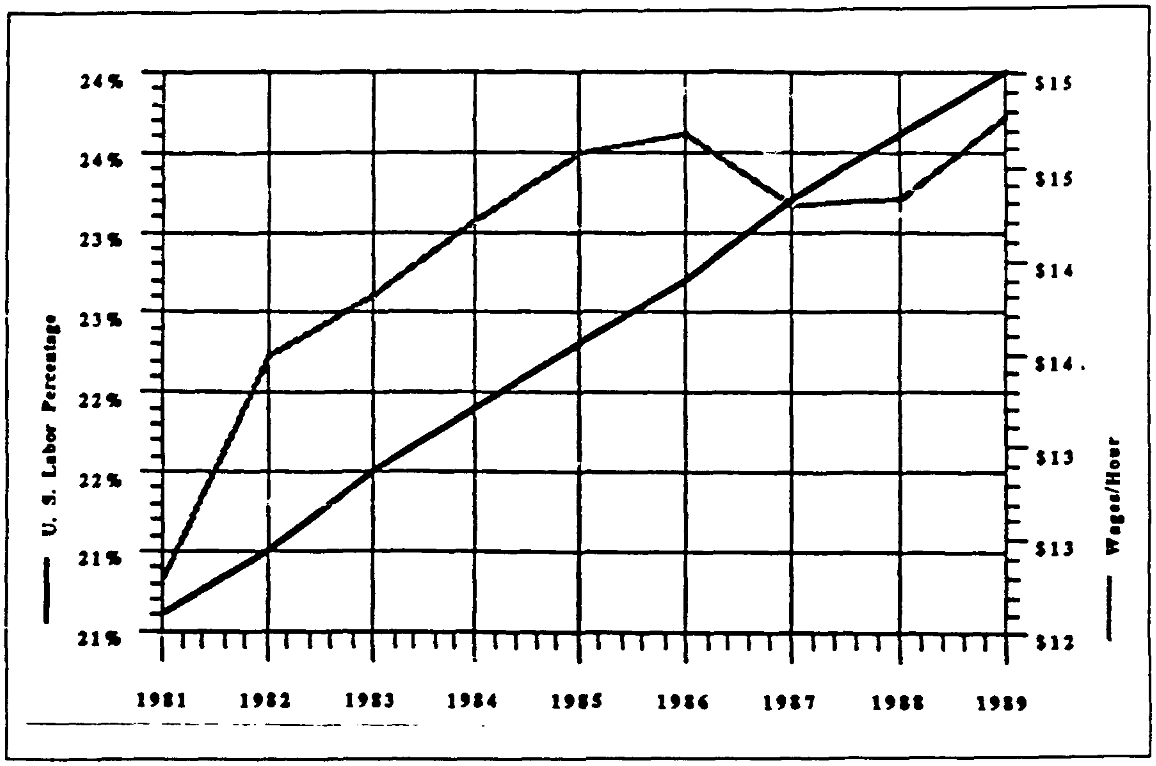

Figure 11. U.S. Labor Cost vs U.S. Wages (1981-1989)

b. U.S. Material Costs

Material costs as a percentage of the total fell during the 1980's, but the decline was not nearly so dramatic as those experienced in Japan or Northern Europe. U.S. steel prices reached their peak during 1983 at $517.09 per metric ton. Prices bottomed out at $387.08 per metric ton in 1987, but rebounded smartly during 1988 and 1989. The U.S. steel price in 1989 was $478 per metric ton. Figure 12 displays the relationship between U.S. steel prices and U.S. material costs during the 1980's.

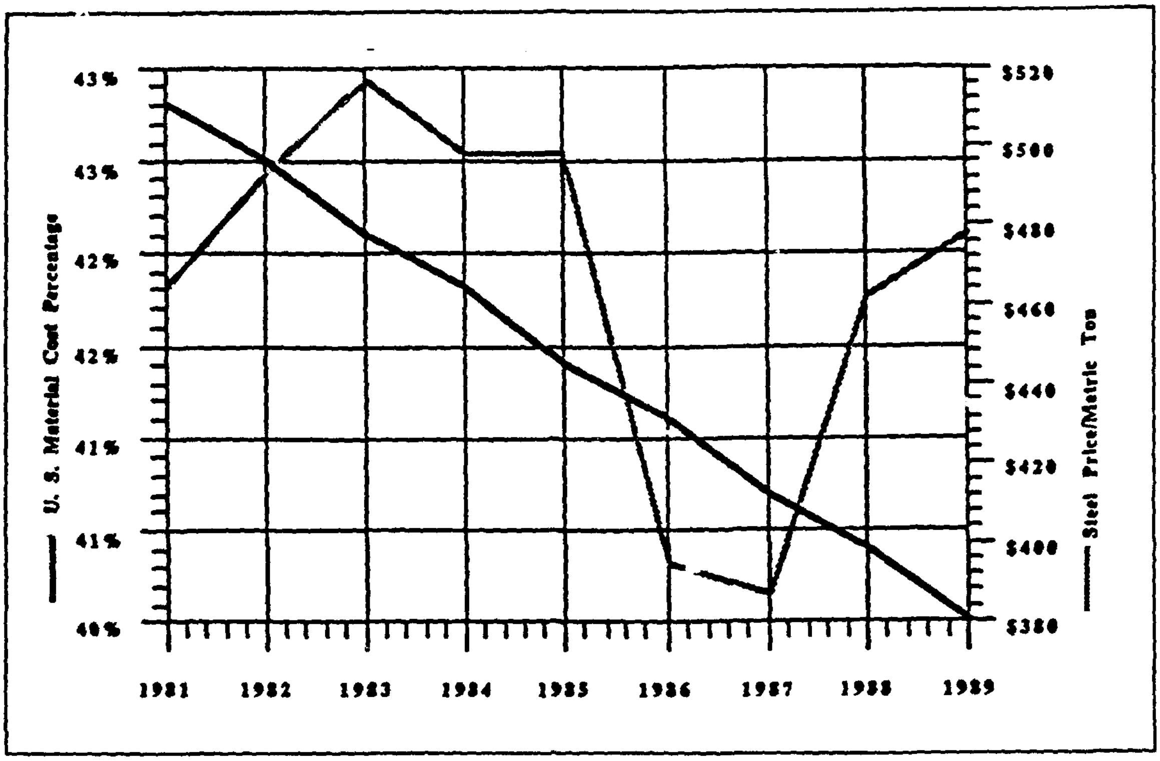

Figure 12. U.S. Material Cost vs U.S. Steel Price (1981-1989)

c. *U.S. Overhead Costs*

Fixed overhead costs declined modestly in the U.S. during the 1980's. Despite dismal commercial newbuilding throughput and disadvantageous borrowing rates for new capital, this phenomenon might best be explained by the shrinking number of private U.S. yards engaged in shipbuilding.

> In 1980 the Maritime Administration MARAD listed 25 shipyards in the active privately owned shipbuilding base. By 1988, this number had dropped to 19, and events in 1989 will see this number drop further to 10 yards actively engaged in ship construction [Ref. 7: p. 29].

Variable overhead costs climbed from 20 percent of the total in 1981 to 24 percent of the total in 1989. As mentioned previously, U.S. yards suffer a distinct disadvantage with respect to costly worker medical benefits which are counted as indirect burdened labor manhours and are included as variable cost.

C. PRODUCTIVITY

At this point, having reviewed the cost structures of Japan, Europe and the United States separately both in local and relative terms, it is appropriate to discuss the results of the productivity analysis detailed in Chapter III.

1. Data Organization

In this section, data will be organized into comparisons between Japan, Europe and the United States. Comparison will also be made between Northern European and Southern European shipbuilders. Northern European shipbuilders include Belgium, Denmark, Finland, France, West Germany, The Netherlands and Norway. These countries are characterized by high wages relative to their Southern European counterparts. Southern European shipbuilders include Italy, Spain and the United Kingdom. Despite its geographical location, the United Kingdom has been included in this category because its labor force, like those of Italy and Spain, earns relatively less than its Northern European counterparts. The Carson and Lamb study [Ref. 7: p. 21] also categorizes the United Kingdom with Southern European shipbuilders. For tables, figures and narrative, the word "Europe" refers to all 10 European countries cited above.

It is hoped that by using averages with respect to European productivity data, that anomalies present within individual countries will be minimized for the entire area. The productivity results for each individual country are included in Appendix F.

2. Labor Productivity

Labor productivity as described in this study is measured in manhours per ship. The fewer the manhours required for ship construction, the more productive the shipbuilding nation or area. Table 23 on page 46 and Figure 13 show the results of the manhour comparison between Japan, Europe and the United States during the 1980's. Several interesting observations can be made from a review of this data.

In 1981, Japanese shipbuilders expended 756,265 manhours to construct a ship in which European shipbuilders expended 907,441 hours to build and U.S. shipbuilding expended 1,350,966 to build. Therefore, U.S. shipbuilders during this timeframe were only 56 percent as productive as their Japanese counterparts. This result approximates the A.P. Appledore study cited in the Office of Technology Assessment study [Ref. 6: p. 109] and frequently mentioned in shipbuilding literature as a principal reason for the decline of the U.S. shipbuilding industry. During this period, U.S. shipbuilders were only 83 percent as productive as European shipbuilders.

Table 23. PRODUCTIVITY COMPARISON BETWEEN JAPAN, EUROPE, AND U.S. IN MANHOURS PER SHIP (1981-1989)

Year	Japan	Europe	United States
1981	756,265	907,442	1,350,967
1982	846,300	897,855	1,012,206
1983	973,963	1,131,734	1,084,231
1984	1,178,194	1,406,850	1,170,578
1985	1,415,975	1,631,173	1,322,601
1986	973,527	1,321,635	1,144,731
1987	859,034	1,166,016	1,100,286
1988	830,774	1,372,205	1,243,404
1989	777,980	1,420,257	1,160,887

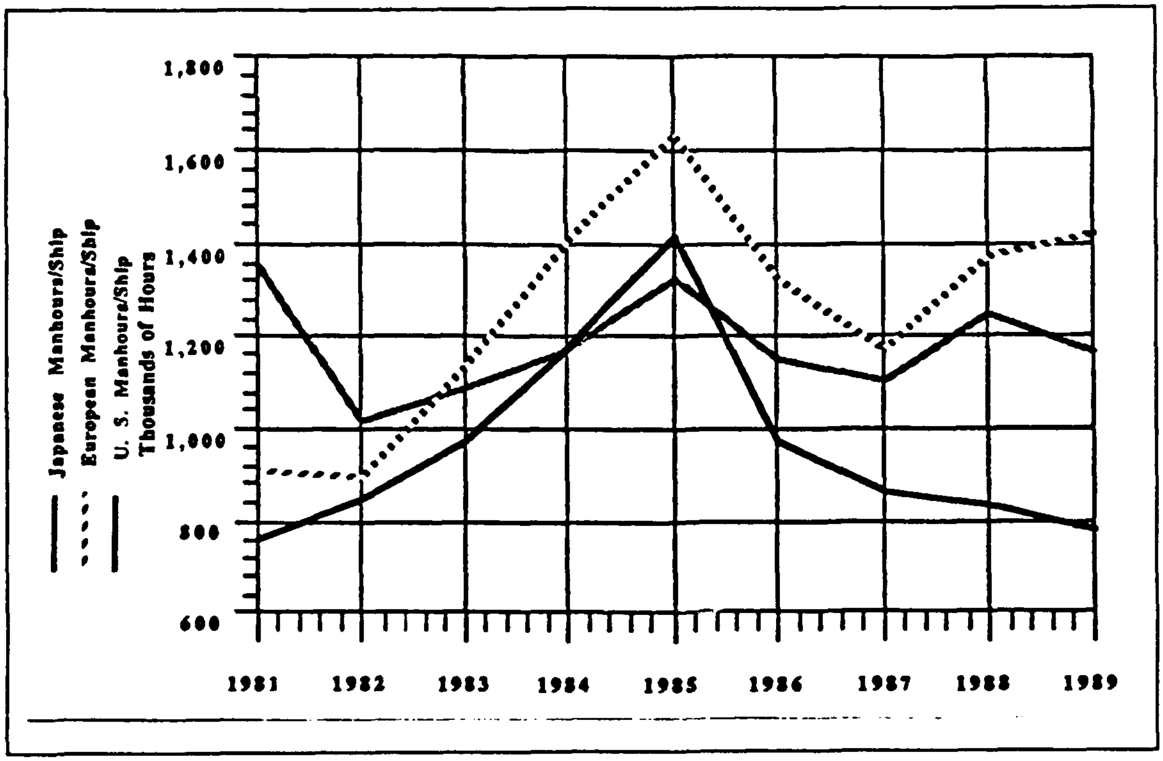

Figure 13. Labor Productivity Comparison Between Japan, Europe, and the U.S. in Manhours (1981-1989)

By the end of the decade, Japanese shipbuilders were expending 777,980 manhours per ship, Europeans were expending 1,420,256 manhours per ship, and U.S. shipbuilders were expending 1,160,886 manhours per ship. U.S. shipbuilders had become 67 percent as productive as their Japanese counterparts and had eclipsed Europe by a fairly wide margin. One reason for the overall increase in total manhours per ship experienced in Japan and Europe, is the increasing complexity of the ships being built. A similar comparison including only Northern European shipbuilders in the labor analysis with Japan and the U.S, as shown in Figure 14, revealed that U.S. shipbuilders expended fewer hours per ship that did Northern European builders from 1984 through 1986, but expended more hours per ship from 1986 through 1988. In 1989, Northern European manhours per ship exceeded U.S. manhours per ship by a narrow margin.

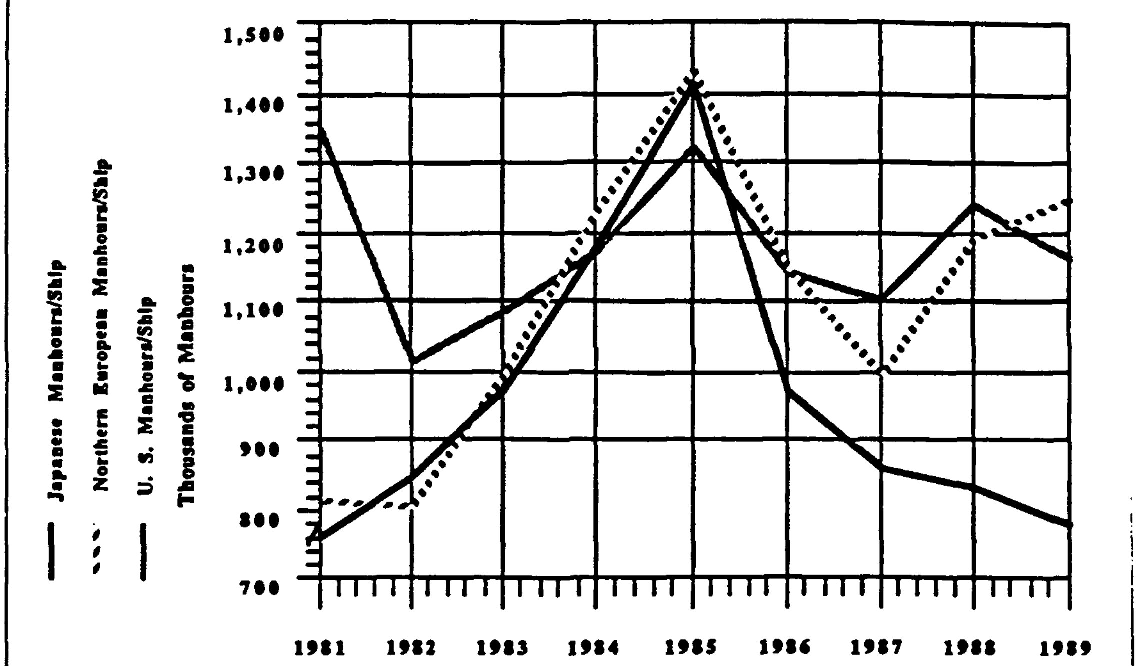

Figure 14. Labor Productivity Comparison Between Japan, Northern Europe, and the U.S. in Manhours (1981-1989)

A contrast of Northern and Southern European labor productivity during the 1980's can be seen in Figure 15. The principal factor driving higher manhours per ship in the Southern European sector is the lower wages earned by workers in these countries.

This would seem to be indicative of shipbuilding operations which are more labor intensive and less automated than those prevalent in Northern Europe, Japan or the U.S.

An obvious anomaly present in Table 23 on page 46 and Figure 13, is that U.S. labor productivity seemingly exceeded that of Japan during the middle portion of the 1980's. However, before concluding that U.S. labor enjoyed a temporary advantage over Japanese labor during this period, one deficiency of the model itself needs to be considered. Japan enjoyed its highest output years of the decade during 1984 and 1985 when it produced 8,972,974 GT in 1984 and 8,763,957 GT in 1985 as shown in Table 19 on page 33. During 1985, the percentage of total local cost expended on labor in Japan was 35.2 percent as shown in Table 15 which was a high point for that country during the decade. A reasonable assumption can be made that labor overtime was used to satisfy customer delivery schedule commitments. While high local cost percentage data is captured to account for the additional costs in the numerator of equation (3.3) in Chapter III, the denominator in the model reflects a primarily regular wage rate per hour. This would tend to artificially inflate the number of manhours utilized in ship construction when extensive overtime wage rates were paid.

To summarize, while Japan continues to enjoy significant labor productivity advantages over its competitors, U.S shipyard labor productivity now exceeds that of Europe. Several reasons, which are discussed below, existed for Japan's continued lead in labor productivity.

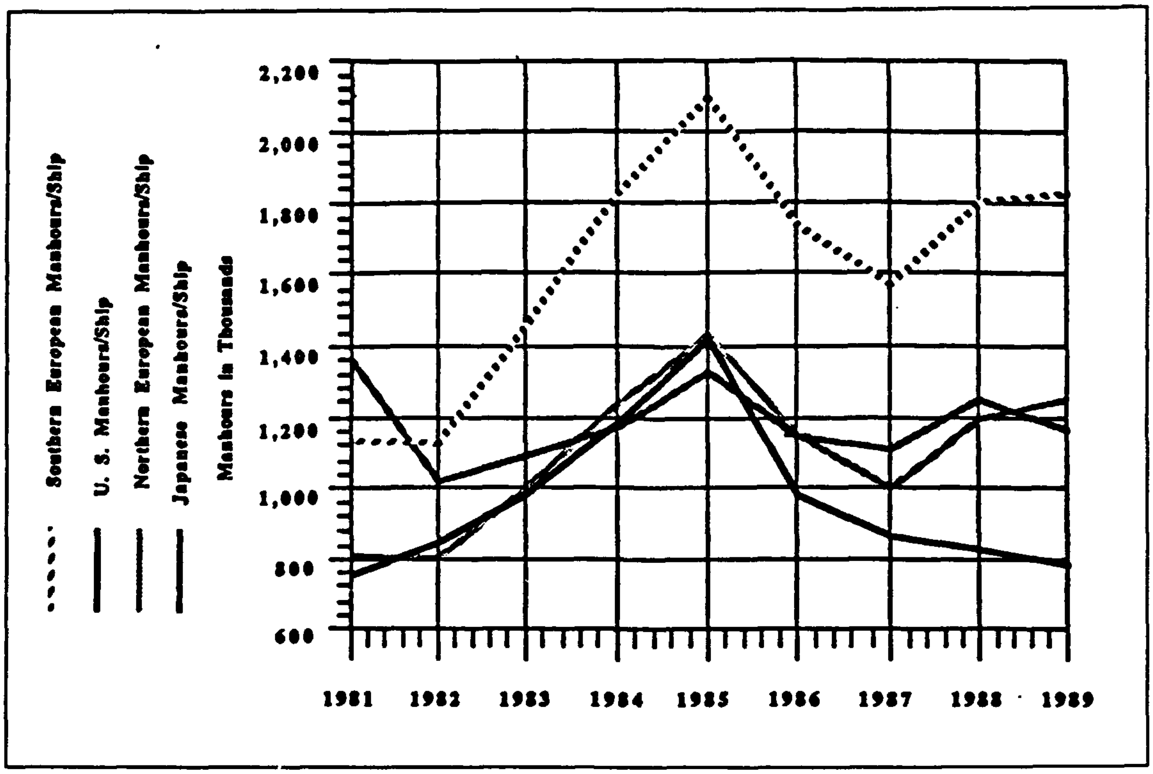

Figure 15. Labor Productivity Comparison Between Northern Europe, Southern Europe and the U.S. in Manhours (1981-1989)

Learning curve/experience curve benefits which accrued from the production of in excess of 63,000,000 GT of shipping during the 1980's, as shown in Table 19 on page 33, undoubtedly gave Japanese yards a distinct advantage.

The "process lane system", used by Japanese shipyards in the 1980's, categorizes all the processes into groups consisting of those with similar work content and allocates them to specified areas in the yard. The purpose of the system is to guarantee stable product quality and to improve productivity by fixing the workers in specified areas [Ref. 27: p. 108]. This method in effect moves the work to the worker and eliminates time wasted in alternative shipbuilding methods in which workers move from job to job in different areas of the shipyard. It also produces workers with specialized skills and encourages more active supervisory attention and better span of control than do other shipbuilding schemes.

Japanese shipyards also use "zone outfitting" methods in newbuilding which consists of "block outfitting, fitting packages and on board outfitting. The purpose of this method is to execute outfitting in an environment with more ease and safety to workers" [Ref. 27: p. 108]. In this scheme the movement of workers and materials in minimized. Work is completed by zone which eliminates the waste of time entailed in shifting workers to assignments in different areas.

> Incorporation of design features which minimize labor manhours provided another advantage. Design engineers in Japan do not merely produce drawings for shipbuilding, but are expected to incorporate designs which facilitate cost reduction and can be easily executed by workers [Ref. 27: p. 109].

The reduction of total material quantities and categories led to the reduction of production manhours in Japan [Ref. 27: p. 107]. Japanese workers wasted less time looking for the right materials or tools necessary to perform their work assignments. Improvements in industrial automation have been incorporated by Japanese yards.

"Advanced carbon dioxide semi-automatic welding machines now dominate" [Ref. 27: p. 111]. Seventy percent of the welding at one Japanese yard (IHI) is now performed in an automated fashion by these machines [Ref. 27: p. 111]. Japanese yards have also automated the burning process. Incorporation of "electro-photo marking (EPM) numerical control (N/C) gas burning machines and plasma burning machines resulted in greater speed and accuracy in the burning process" [Ref. 27: p. 111].

Improvements in the work environment have also helped the Japanese gain a manhour productivity advantage. Some examples follow:

1. All zone outfitting areas in one yard have been weather proofed to shield workers from the elements [Ref. 27: p. 111].
2. Simplified scaffolding has been designed to reduce set up and break down time in one Japanese yard [Ref. 27: p. 111].
3. Even hand tool improvements have contributed to productivity enhancements. Where possible, lighter and quieter tools have been substituted for heavier, noisier ones to ease the workers' daily burden [Ref. 27: p. 111].
4. In the organizational area, IHI cites a specific "target achievement" goal oriented process and smaller work groups as contributors to increased labor productivity [Ref. 27: p. 112].

It is perhaps not surprising that the one U.S. shipyard with any substantial orderbook as shown in Table 4, Avondale Industries, in New Orleans, Louisiana has worked closely with Japanese consultants from IHI through the Naval Shipbuilding Research Program (NSRP) to improve its shipbuilding process.

It should also be emphasized that the apparent U.S. labor productivity advantage over European shipbuilders is based strictly on cost structure and wage data. As previously emphasized in Chapter II, the U.S. output of commercial gross tonnage is very small compared to European nations like Germany, Denmark and Spain. U.S. wage data is based on an industry primarily engaged in military rather than commercial shipbuilding. A fairer statement about the comparison between European and U.S. shipbuilders might be that if U.S. shipbuilders were more actively engaged in commercial shipbuilding, they would enjoy a labor productivity advantage.

3. Material Productivity

Material productivity as described in this study is measured in metric tons of steel per ship. The fewer metric tons of steel required for ship construction, the more productive the shipbuilding nation or area. Table 24 and Figure 16 show the results of material productivity comparison between Japan, U.S., Northern Europe and Southern Europe. Some interesting observations can be made from a review of this data.

Table 24. PRODUCTIVITY COMPARISON BETWEEN JAPAN, NORTHERN EUROPE, SOUTHERN EUROPE, AND U.S. IN METRIC TONS OF STEEL PER SHIP (1981-1989)

Year	Japan	Northern Europe	Southern Europe	United States
1981	62,305	80,663	69,322	74,346
1982	52,374	53,432	50,753	56,012
1983	49,255	52,456	51,223	56,711
1984	46,015	53,193	53,236	63,753
1985	46,617	52,895	54,191	71,838
1986	42,743	43,531	42,071	76,976
1987	40,106	40,657	41,064	71,274
1988	43,049	50,215	50,578	66,022
1989	49,045	55,119	54,945	59,785

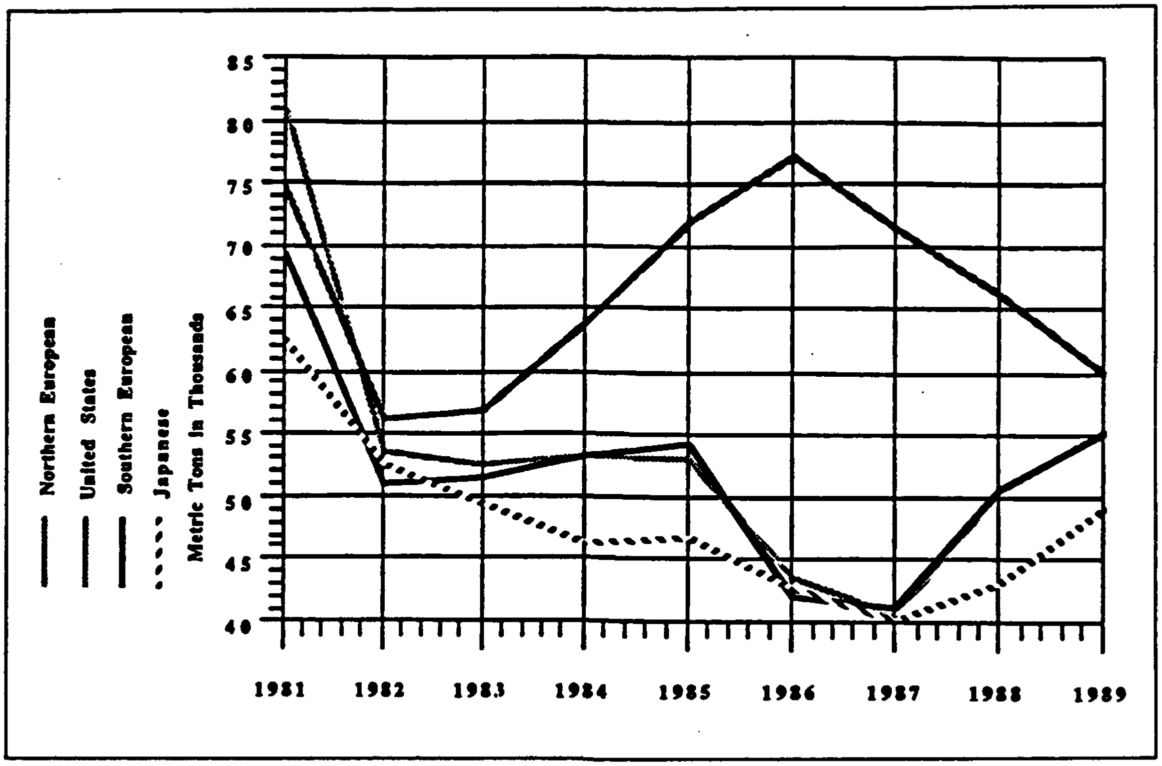

Figure 16. Manhour Productivity Comparison for Japan, N. Europe, S. Europe, and the U.S. in Metric Tons of Steel Per Ship (1981-1989)

While Japan was clearly the leader in material productivity for most of the decade, its curve moves in the same general direction as those of Northern Europe, and Southern Europe. There is very little difference in material productivity between Northern and Southern European shipbuilders. The U.S. is by far the least efficient nation with respect to material productivity, but seems to have substantially narrowed the gap with other nations.

It appears that Japan, Northern Europe, and Southern Europe responded to the falling newbuilding price phenomenon experienced from 1981 to 1985 by using material more efficiently. It is also interesting to note that material productivity continued to improve until 1987, in these three areas, fully two years after the trough in world newbuilding prices was experienced in 1985. As indicated earlier, in Figures 4 and 7, steel prices which rose sharply in relative terms because of a weaker dollar, as shown in Tables 8, 9 and 10, and would seem to account for most of the improved material productivity.

Several explanations are offered for Japan's shipbuilding leadership positions in material productivity. Standardization is used by Japanese shipbuilders in the categorization of materials used in shipbuilding. This eliminates waste in the form of scrap rejected due to variation in acceptable quality standards [Ref. 27: p. 107]. Japanese management techniques also foster long term relationships with suppliers to acquire desired quality in materials obtained.

Just-In-Time inventory management techniques are utilized by Japanese shipbuilders. This technique reduces inventory holding costs to an absolute minimum since shipbuilding supplies arrive only when needed. This management method also tends to reduce fixed overhead costs by minimizing warehouse space required to store supplies [Ref. 27: p. 107].

Japanese shipbuilders also seemed to coordinate requirements better between their design department and their material procurement area to minimize leadtimes in acquiring material [Ref. 27: p. 107].

More precise control using automated welding and burning equipment would also account for less material scrappage [Ref. 27: p. 111].

Within the scope of the present methodology, much of the disadvantage which the U.S. suffers in material productivity is driven by the relatively high composite ship cost and almost flat percentage of cost accounted for by material. Obstacles which the U.S. must overcome in order to improve material productivity are discussed in the next chapter.

4. Overhead Productivity

While little can be said quantitatively about overhead productivity because of the difficulty described in Chapter III of selecting an appropriate unit for extracting the data, Table 25 on page 54, Table 26 on page 54, and Table 27 on page 55, list cost (both fixed and variable) per ship in dollars in Japan, Europe, and the United States over time using information from Tables 14 through 17.

Table 25. JAPANESE OVERHEAD PER SHIP IN DOLLARS: 1981-1989

Year	Fixed	Variable	Total
1981	1,866,191	5,781,533	7,647,724
1982	1,455,595	4,508,103	5,963,698
1983	1,517,411	4,698,138	6,215,549
1984	1,587,074	4,912,371	6,499,445
1985	1,731,191	5,356,892	7,088,083
1986	2,444,258	6,145,565	8,589,823
1987	3,331,313	7,236,992	10,568,305
1988	5,116,933	9,985,472	15,102,405
1989	6,429,835	11,412,962	17,842,797

Table 26. EUROPEAN OVERHEAD PER SHIP IN DOLLARS: 1981-1989

Year	**Fixed**	**Variable**	**Total**
1981	2,572,693	8,214,568	10,787,261
1982	1,845,502	5,912,446	7,757,948
1983	1,747,463	5,653,556	7,401,019
1984	1,666,127	5,414,914	7,081,041
1985	1,633,229	5,335,214	6,968,443
1986	2,472,358	6,634,162	9,106,520
1987	3,470,448	8,347,841	11,818,289
1988	5,550,305	11,973,691	17,523,996
1989	7,132,836	14,265,673	21,398,509

As mentioned earlier in the discussion of the cost structures prevalent in Japan, Europe and the U.S., those areas with lower costs of capital and high shipyard throughput enjoy an advantage in the realm of fixed overhead. Indirect manhours which are considered a variable overhead cost are negatively influenced by costly worker medical benefits.

Another factor pertinent to fixed overhead cost which has enabled Japan to continue to achieve lower costs than its competitors, is capacity management as shown

Table 27. UNITED STATES OVERHEAD PER SHIP IN DOLLARS: 1981-1989

Year	Fixed	Variable	Total
1981	13,379,428	16,119,794	29,499,222
1982	10,395,835	13,319,665	23,715,500
1983	10,725,016	14,625,023	25,350,039
1984	11,241,186	16,330,104	27,571,290
1985	12,357,194	19,011,056	31,368,250
1986	10,135,116	16,645,267	26,780,383
1987	8,878,126	15,587,552	24,465,678
1988	9,437,500	17,742,480	27,179,980
1989	8,573,154	17,146,304	25,719,458

in Figure 17. While shipyards throughout the world closed during the 1980's, mostly in response to low demand and low newbuilding prices, the Japanese shipbuilding industry has apparently formulated a strategy designed to overcome the adverse productivity effect of too many underutilized shipyards. Figure 17, reproduced from *Shipyard Weekly* [Ref. 18: p. 48], indicates that Japan, even during periods of increasing demand, has continued to relentlessly slash yard capacity in an effort to squeeze the most productivity from its facilities.

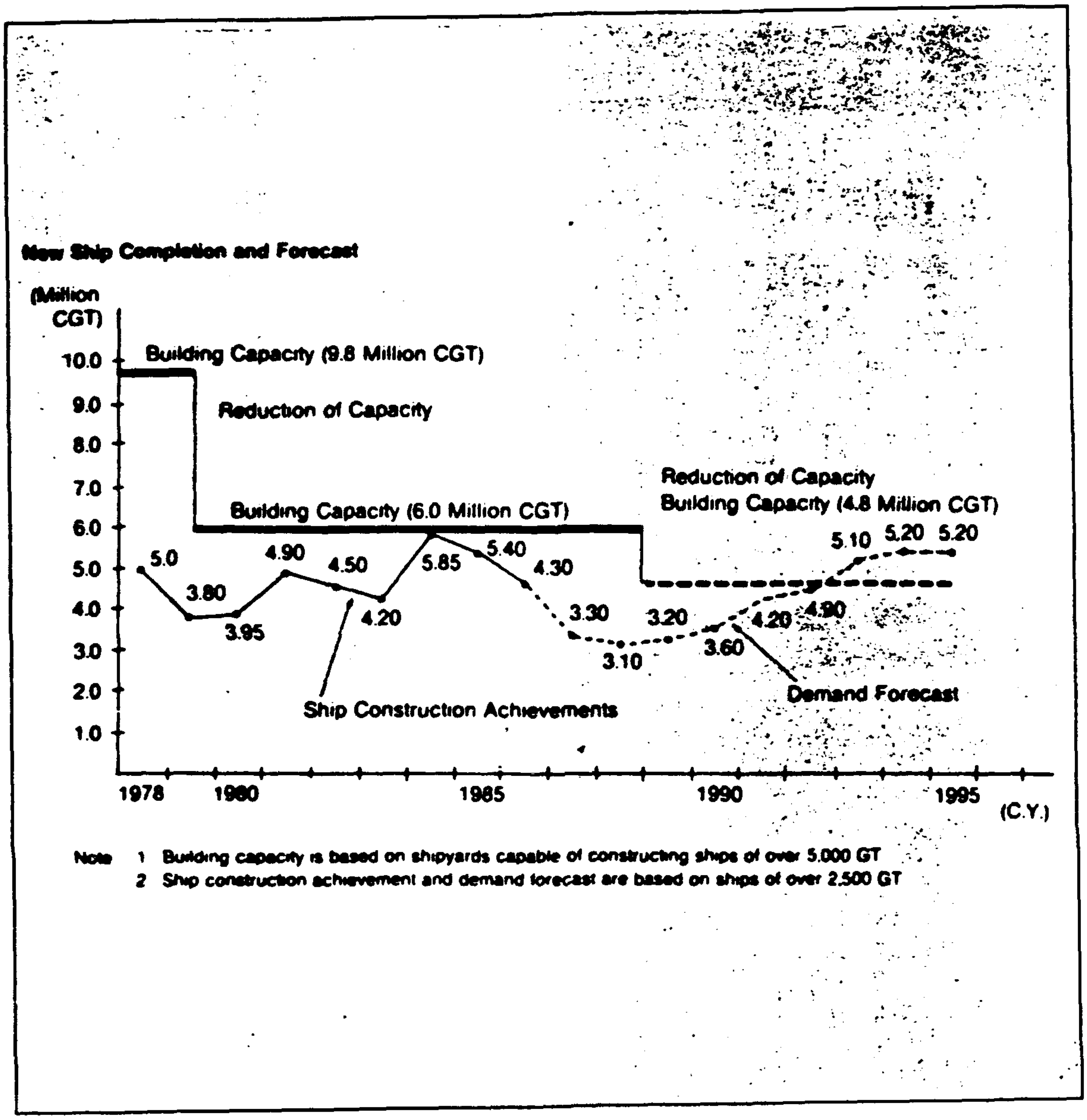

Figure 17. Japanese Capacity Management(1978-1995)

V. QUALITATIVE ASSESSMENTS

A. GENERAL OVERVIEW

Chapter IV quantitatively underscores relative labor and material productivity in U.S. commercial shipyards. It depicts a U.S. commercial shipbuilding industry whose labor productivity has improved but still lags that achieved by Japan. It also points out material productivity disadvantages the U.S. suffers from when compared to Japan and Europe. Although material productivity in U.S. yards is improving, it is worth noting that the metric ton gap between the U.S. and its competitors, shown in Table 24 and Figure 16, translates into millions of dollars per ship. Perhaps most significant is the fact that much of the apparent improvement of relative U.S. ship cost is based on a dollar which has weakened markedly since 1985.

This chapter will discuss other obstacles which the U.S. commercial shipbuilding industry faces in meeting the competitive goals detailed in Chapter II. These obstacles fall into three categories:

1. Fierce International Competition
2. Ineffective U.S. Government Policy
3. The American Business Environment

B. FIERCE INTERNATIONAL COMPETITION

Aside from the nations included in the quantitative portion of this study, there are a host of other countries capable of producing high quality, low cost commercial ships. This section will discuss the strengths and weaknesses of several current and potential shipbuilding powerhouses.

1. South Korea

The world's most dramatic shipbuilding success story in the past 15 years has been the nation of South Korea. "From 5.7% of the world market in 1975, the Korean builders rose to 9% in 1980, 19.2% in 1983, and 30.2% in 1987." [Ref. 29: p. 49]. As Table 1 illustrates, Korean shipbuilders' rank second behind Japan in total GT produced.

Collectively, the three major yards, Hyundai Heavy Industries (HHI), Samsung, and Daewoo, are capable of building virtually every conceivable ship type including Very

Large Crude Carriers (VLCC's), container ships, chemical tankers, liquid petroleum gas (LPG) carriers, semi-submersible drilling rigs, and passenger vessels.

Despite wages which are less than half of those earned in Europe, Japan, and the U.S., it would be erroneous to conclude that Korea owes its dominant position in world shipbuilding to cheap labor alone. At least one yard, "Inchon Engineering utilizes Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) in its ship design and building program", [Ref. 30: p. 389]. Significant engineering expertise is also evidenced by the fact that "Hyundai Heavy Industry (HHI) is known to be exporting a full package of design documentation for an 88,900 DWT crude carrier to the Portuguese yard of Setenave", [Ref. 30: p. 389]. C. Y. Lee, general manager of the Korean Shipbuilders Association notes that "Korean shipbuilders are fully booked until late 1992 and expects that the demand to replace old tonnage will increase until at least 2000", [Ref. 31: p. 41].

The Porter and Cho study describes the nation's shipbuilding industry in the following manner:

> Korean shipbuilders are acclaimed as the most efficient in the world. Their labor force is disciplined and works twelve hours per day. Night shifts are available if needed. Yards seldom miss delivery schedules and in many cases significantly shorten the normal building period from twenty four to thirty months by as much as ten to fifteen months [Ref. 15: p. 560].

Despite considerable engineering expertise and a reputation for producing low cost, high quality ships, Korean shipbuilders would seem to have been the victims of their own success. By vying relentlessly with the Japanese for increased market share during the 1980's, Korean shipyards accumulated enormous losses during the 1980's. "At the end of 1987 total debts of the four major yards were Won 3700 billion ($5.43 billion dollars)" [Ref. 29: p. 49].

In addition, input costs to the labor process have risen dramatically. The Jenks and Larner study [Ref. 13: p. 13] reported steel prices at $310 per metric ton in 1981. By 1986 Carson and Lamb [Ref. 7: p. 7] report that prices had fallen to $280 per metric ton. However, in 1989 Carson and Lamb [Ref. 7: p. 7] indicate Korean steel prices had risen to nearly $500 per metric ton which ranks (by this author's estimate) as one of the highest of the major shipbuilding nations in the world.

Additionally, labor costs have risen astronomically from 1981 to 1989. In 1981, Korean workers earned (Won 1403) or $2.06 per hour. In 1989, workers earned (Won 4263) or $6.35 per hour. The big three yards, HHI, Samsung, and Daewoo, all suffered major strikes during 1989 and 1990 which resulted in a substantial number of lost orders and wage concessions to laborers.

2. Peoples' Republic of China

A nation with more than a billion people would seem to have a remarkable advantage in a labor intensive industry such as shipbuilding. In fact, the Porter and Cho study [Ref. 15: p. 562] and Carson and Lamb study [Ref. 7: p. 7] forecast that China will become a low cost leader in shipbuilding during the 1990's.

The environment seems particularly favorable for the growth of shipbuilding in this nation. While actual data is not available on wages per hour in China, "Labor costs in China are known to be low" [Ref. 32: p. 51]. This translates into cheaper contract prices. Actual newbuilding costs average 5-10 percent less in China than in Japan and South Korea [Ref. 32: p. 51].

Additionally, the government is committed to making the shipbuilding industry work. The China State Shipbuilding Corporation (CSSC) has ambitions of "turning out high tech ships" [Ref. 32: p. 51]. In support of this vision, CSSC has some 30 research and development centers under its jurisdiction. "The largest, the China Ship Scientific Research Center, employs 500 engineers" to create the designs for these high tech ships [Ref. 32: p. 51]. The Chinese government has designated six universities to graduate a total of 3,000 shipbuilding engineers every year. This means that there are currently more shipbuilding engineers in China than the entire work force of approximately "10,000 people" [Ref. 7: p. 30] dedicated to commercial shipbuilding in the U.S.

CSSC has imported technology as a method of accelerating the growth of their shipbuilding industry.

> CSSC has now procured the technology, either through license or coproduction agreements, to produce 50 types of equipment such as engines, generators, cranes, and hydraulic deck machinery [Ref. 32: p. 51].

Another remarkable aspect of the Chinese shipbuilding industry is the fact that individual yards do not function merely as installers of major equipment. Yards such as Hudong in Shanghai are vertically integrated factories which in essence convert raw materials into ships.

> It has traditionally been the policy in the Peoples' Republic of China that each enterprise is assigned a mission and then it is to develop itself both vertically and horizontally to accomplish the mission...Hudong for example, builds its own engines, makes its own valves and fittings and makes all of the castings and forgings that are required. Likewise, all of the support services necessary to design and build a ship are contained within the shipyard organization [Ref. 33: p. 255].

Critics of Chinese shipbuilding point out several areas in which the nation suffers serious disadvantages. These include:

- "Productivity levels as low as 10% of those achieved in Japan" [Ref. 34: p. 79].
- "Most shipyards with the notable exception of the nation's largest, Dalian, are located along relatively shallow rivers constraining ability for expansion",
- "High material cost is another disadvantage. The costs of raw materials currently accounts for approximately 70 % of the total ship cost",
- "The presence of inefficient socialist system management which accounts for frequent delivery delay is cited as another weakness" [Ref. 32: p. 53].

While Chinese shipbuilders are currently devoted to the construction of a substantial domestic fleet, the export market brings in much needed foreign exchange [Ref. 32: p. 51]. "The question now appears to be not so much if China will be a leading shipbuilding power but when" [Ref. 32: p. 50].

3. Former Eastern Block Countries

The fabric of the post cold-war world offers the potential for increased shipbuilding business opportunities in the nations of Eastern Europe. Several offer highly advanced shipbuilding capability, labor forces earning comparatively low wages, and a desire to parlay their new found autonomy and shipbuilding export experience into money making ventures. Indeed, four of the top 20 entries from Table 1, Merchant Ships Completed During 1989, are countries formerly aligned closely with the USSR: Yugoslavia, Romania, German Democratic Republic, and Poland.

a. Yugoslavia

Yugoslavia currently ranks as the world's third largest shipbuilder. "About 95% of the orders placed in Yugoslavia are for export" [Ref. 35: p. 17]. Yugoslavia has long been a builder of ships for the Soviet Union and this is not likely to change with the new world order.

> Recently Soviet shipping delegates visited the big yards for talks on the next five year shipbuilding plan and while nobody was willing to comment in depth on the outcome of the talks, it is widely accepted that the Soviets are turning their attention to the construction of cruise vessels to replace an aging passenger fleet [Ref. 35: pp. 17-18].

Despite a formidable shipbuilding industry, Yugoslavia faces severe economic problems. Inflation during 1986 reached a staggering 2600 percent [Ref. 36: p. 14]. Additionally, the three major shipyards, Uljanik, Split, and Treci Maj, who employ approximately 7000 workers, each realize that the work force needs to be reduced in order to remain competitive [Ref. 36: p. 14]. One yard is trying to couple a sense of social consciousness with business acumen in handling the industry wide layoffs. Lenac, a mid-sized yard, has offered laid-off workers an opportunity to compete as subcontractors. The only stipulation is that the yard keep a majority stake in the operation of these new found companies. Lenac hopes to reduce its subcontracting costs and keep former employees under the yard umbrella by implementing this strategy [Ref. 37: p. 19].

b. Romania

While little information was readily available about this nation, Romania ranked 9th in gross tonnage completed during 1989. The yards hold an orderbook of some 585,204 DWT for their domestic fleet and export customers, such as the USSR, Cuba, and China. The major yards in Romania are Braila, Constantza, Galatz, Mangalia, and Turnu [Ref. 4: pp. vii, 25- 26].

c. German Democratic Republic

The fall of the Berlin Wall has some interesting implications for the world shipbuilding community. Table 28 indicates that if the gross tonnage output of East and West Germany were totalled for the years 1987, 1988, and 1989, a unified Germany would have comfortably been the third largest producer in the world behind Japan and Korea [Ref. 3: p. 3; Ref. 25: pp. 1-2; and Ref. 26: pp. 1-2].

Table 28. OUTPUT OF WEST GERMANY (FRG) AND EAST GERMANY (GDR) IN GT: 1987-1989

YEAR	FRG	GDR	TOTAL
1987	341,319	292,241	633,560
1988	521,156	292,221	813,377
1989	430,849	287,185	718,034

Regardless of the form that restructuring takes in the shipyards of a new unified Germany, this nation will be a powerful force in the world shipbuilding scene of the future. One particularly advantageous aspect of the unification is that the new nation can draw upon established export customer pools in both Eastern and Western Europe.

d. Poland

Poland possesses a long-standing reputation as a nation that builds quality export tonnage. Polish shipyards are capable of building virtually all modern commercial ship types including containers, reefers, passenger vessels, and crude oil carriers. Their current orderbook contains 63 ships totalling 1,441,580 DWT [Ref. 4: p. vii]. The largest customer, by far, of the Polish yards is the Soviet Union. However, Poland is also contracted to manufacture ships for Norway, France, West Germany, Finland, India, and Czechoslovakia [Ref. 4: pp. 24-25], The appearance of the names of several prominent Northern European shipbuilding nations in the Polish orderbook makes a strong statement about the quality and cost of ships being built in Poland. The largest Polish shipyards are Szczecin, Pary, Gdanska, Polnocna, and Remontowa [Ref. 4: pp. 24-25].

e. Eastern European Summary

The impressive commercial shipbuilding credentials possessed by the Eastern European shipbuilders have not gone unnoticed by other global competitors.

> A Japanese delegation comprising members of the country's shipbuilding sector has embarked on a fact finding mission to eastern Europe. Included in the numbers are top officials from the Shipbuilding Committee of the Council for Rationalization of Shipping and Shipbuilding Industries, the Shipbuilders' Association of Japan (SAJ), and a major Japanese shipbuilder, Mitsui Engineering and Shipbuilding Company. A spokesman for the delegation commented, "It is hoped to improve the level of international co-operations between Japan and the chief shipbuilding nations of eastern Europe, Poland, Germany, and Yugoslavia" [Ref. 38: p. 7].

This author speculates that Japan, faced with rising labor and material costs domestically, is anxious to export its advanced technology to low labor cost areas perhaps in some manner of "transplant" arrangement similar to those entered into with the American automobile industry.

4. Brazil

Outside the eastern block, one shipbuilding nation with a healthy orderbook and rather unique financing mechanism is the South American nation of Brazil. Brazil currently possesses the world's third largest orderbook totalling 3,595,005 DWT [Ref. 4: p. vii]. The vast preponderance of orders at the major yards, East Caneco, Ishibras, and Verolme, are for expansion of a growing domestic fleet which export everything from lumber to oranges [Ref. 4: p. 14] and [Ref. 39: p. 17].

Brazil has hopes of converting some of its international debt burden into ship exports [Ref. 40: p. 7]. The elaborate financing scheme which enables Brazil to offer competitive pricing, direct business to its yards, and reduce its debt is described below:

> In the hypothetical case of a Brazilian ship selling for $75 million and costing 50% more than a comparable South Korean bottom, buyer and yard would negotiate

specifications and delivery time of the ship to be built and exported. Contract in hand, the buyer would purchase Brazilian debt certificates worth $98 million from a creditor bank. Since the Brazilian paper sells for 50% off face value the buyer actually receives a price $1 million less than the South Korean price. Presented with the certificates, the central bank would wipe $98 million from its international debt and authorize the release of $75 million worth of cruzados to the shipyard, a 23.5% discount from the face value of the converted certificates [Ref. 40: p. 5].

"Brazilian yards have a good record on quality and can build more than simple ship types" [Ref. 41: p. 26].

It is also worth mentioning that U.S. owner Chevron is purchasing three, 150,000 DWT crude oil carriers from the Ishibras shipyard in Rio de Janiero for delivery in 1991 [Ref. 4: p. 14].

Brazil stands to gain from the fact that interested Scandinavian owners are being turned away from Asian shipyards who are booked to capacity through 1992 [Ref. 41: p. 26].

5. Competitive Summary

It is against these formidable competitors that the U.S. commercial shipbuilding industry has hopes of re-emergence. The outlook for successful recovery is doubtful. The next two sections will discuss other obstacles the U.S. commercial shipbuilding industry must overcome.

C. INEFFECTIVE U.S. GOVERNMENT POLICY

1. Background: No Long Term U.S. Strategy

One of the principal impediments to a reinvigorated industry in the United States continues to be the absence of a cohesive long term government strategy which encourages commercial shipbuilding. As mentioned previously in Chapter II, it is important to remember that while free trade is a noble goal, virtually all international shipbuilders, with the exception of those in the U.S., receive some sort of governmental support.

The very nature of the industry requires commitment as a long term player to be successful. "If there is one lesson to learnt from the past it is that hard times are the norm in commercial shipbuilding" [Ref. 42: p. 41]. Shipbuilding is characterized by boom and bust cycles. It is an industry in which the financial resources involved in expensive waterside facilities, heavy plant and equipment and construction cost are enormous. It is a business in which the pricing of ships below cost is a common practice. The reality of the international marketplace is that no private enterprise can afford to make a go of it in commercial shipbuilding without government assistance.

Yet U.S. government policy with respect to commercial shipbuilding in the past decade has essentially mandated that commercial shipyards go it alone. Public policy in the 1980's achieved short term cost avoidance goals but lacked a vision of the longer term consequences for the industry. For example, when the U.S government suspended Construction Differential Subsidy (CDS) in 1982 because of its onerous cost, it abandoned an ailing industry at a time when it most required government intervention for survival. The cost savings achieved in the early 1980's do not seem as significant when viewing the U.S. shipbuilding industry in its currently underwhelming world position.

John Stocker, President of the Shipbuilders Council of America, made the following statement before Congress, discussing foreign competition and U.S. maritime strategy. It aptly summarizes the short-sightedness of U.S. policy in commercial shipbuilding.

> In short, I would say that one of the reasons that they are good shipyards and why they have been successful in the commercial market, is because their governments have an industrial strategy in regard to shipbuilding, where we have not had such strategy here in the United States [Ref. 5: p. 48].

Some of the consequences of government policy as they relate to future obstacles to U.S. commercial shipbuilding are discussed below. Most illustrate how short term considerations prevailed over long term implications in the policy making process.

2. Lack of Healthy Commercial and Military Mix

One of the few safety nets for U.S. shipbuilders in the 1980's was the Reagan Administration mandate to build the 600 ship Navy. A failure of long range strategy (as seen from the hindsight of a 1990 perspective) is that government neglected to provide for an adequate mix between commercial and military vessels. Shaped by the dollars from the Shipbuilding Construction Navy (SCN) appropriation, U.S. shipyards became almost exclusively the builders of high technology military warships.

It is interesting to note that $31.3 billion, or greater than 95% of the dollars in the collective newbuilding U.S. shipyard orderbook is for U.S Navy vessels [Ref. 43: p. 44]. If U.S. Army and U.S Coast Guard vessels are included, the total percentage of dollars, being spent on military vessels in the U.S. orderbook rises to 97.5 percent [Ref. 43: p. 44].

The departure from the commercial sector of the market enabled competitors in other nations to gain increased advantage in terms of market share and efficiency. It also enabled foreign nations to leapfrog ahead of the U.S. in commercial technology and design development.

Perhaps the most important factor in the neglect of the commercial shipbuilding sector is that U.S. shipbuilders are ill-equipped to transition to a more commerce-oriented and commercially competitive post cold war world. It is indeed ironic that the massive emphasis on military vessel construction which at least in part resulted in bringing the cold war to an end, has to some degree relegated the commercial shipbuilding sector to virtually non-entity status. Equally ironic is the fact that U.S. yards are prevented by Department of Defense Policy from exporting that which they make best, warships [Ref. 44: p. 9].

3. Failure to Recognize Impact on the Industrial Base.

Another dramatic consequence of both a government policy of neglect and a down market for commercial tonnage in general during the 1980's has been the significant reduction of the shipbuilding industrial base.

> In early 1984, the U.S. Navy and the Maritime Administration issued a joint classified report which examined the ability of the private shipbuilding and ship repair sectors to contribute to a national mobilization base. In 1982, the Shipyard Mobilization Base Analysis (SYMBA) study identified 110 private shipyards as essential to the nations's mobilization requirements. 43 of those 110 SYMBA yards have closed leaving only 67 yards or 60.9 in operation today [Ref. 5: p. 52].

An even grimmer scenario is represented by industries which support shipbuilding in this country.

> As bad as the shipbuilding and ship repair industrial base may be, the national infrastructure of manufacturing firms supplying components which are integral parts of both commercial and naval ships may be in worse condition. Across the broad spectrum of machinery including turbines, diesel engines, gears, valves, castings, and forging, delivery lead times are increasing and the number of companies bidding on such work is rapidly decreasing [Ref. 5: p. 55].

4. Lack of Commitment to Research

Another obstacle to progress in U.S. commercial shipbuilding has been the U.S government's sporadic support of the shipbuilding research effort. An extremely capable organization which seemed to be making impressive headway on formulating solutions to shipbuilding productivity problems in the early 1980's was the National Shipbuilding Research Program (NSRP). This organization dedicated itself to attacking virtually all aspects of the U.S. shipbuilding productivity problem. Its panel format pursued better modes of operation in a number of diverse areas including facilities utilization, welding, human resource innovation, and industrial engineering to name only a few.

However, federal budget cutting measures largely eliminated funding for the NSRP in 1984, and the transfer of the NSRP to the U.S. Navy has only recently restored funds to the program [Ref. 7: p. 13].

Germany, Japan, Norway, and Korea all boast government sponsored programs which are actively engaged in the design aspect of future ships. These nations are tackling such diverse innovations as manpower reduction in ship operation; shared computer aided design and computer aided manufacturing (CAD/CAM) in the production process; and greater automation in ship operation [Ref. 7: p. 12]. The United States cannot point to similar government commitment on its part for commercial shipbuilding research.

5. The Deficit

Looming like a dark cloud over any remote prospect of commercial shipbuilding recovery in the United States is the massive federal budget deficit. Volumes of analytical literature continue to be written on the size, scope, and reasons for the U.S. federal budget deficit. The battle for government funds grows increasingly more intense each year. Commercial shipbuilders seeking government assistance can count on very tough struggles to obtain badly needed financing.

One recent example highlights the conflict between Congress and the Department of Defense (DOD) related to the deficit. It illustrates how long term priorities can be obscured by economic reality. This example is particularly relevant since it deals with the future well being of U.S. shipbuilders.

> A portion of the sealift budget ($217.2 million) was reprogrammed to help pay for the defense account shortfalls resulting from an earlier move by the Administration to avoid cuts stemming from Gramm-Rudman budget requirements. This means that $347.8 million remains for sealift out of almost $600 million originally appropriated by Congress in the FY 1990 budget. That the Fast Sealift program has survived at all is a tribute to Congress, despite continued attempts by DOD to kill it [Ref. 45: p. 1].

Another distressing implication for U.S shipbuilders which the deficit and a changing political environment portends, is a reduction of military newbuildings. Since the 600 ship Navy concept has fallen from favor and the cold war has ended, American yards will almost certainly be facing not only a reduction in their newbuilding growth rate, but also the outright cancellation of currently-projected orders for military ships in future years.

D. AMERICAN BUSINESS ENVIRONMENT

American corporate goals and management practices also constitute a formidable obstacle to a resurgence of the U.S. commercial shipbuilding industry. This section will discuss several business factors which continue to prevent U.S. shipyards from becoming more competitive.

1. Profitability

A principal objective of any American chief executive officer (CEO) must be the profitability of the enterprise in which his company is engaged. As the reader can recall from earlier chapters, newbuilding prices in the past decade have rarely covered costs. Even cost efficient shipbuilders in Japan and Korea sustain huge losses. Few American corporations can best serve their shareholders by venturing into the intensely competitive, low profit world of commercial shipbuilding.

2. Short Term Outlook

An obsession with the bottom line, quarterly earnings, and dividend payments has long dominated the American business scene. Commercial shipbuilding requires that a corporation be a long term player to be successful. Success in commercial shipbuilding over the past decade has meant outlasting your competitors. Commercial shipyards in Japan provide an excellent example. Several were capable of absorbing losses for several successive years. This tactic was employed to maintain world market share.

Competitors unable to continue to absorb losses exit the marketplace. Sweden, the paradigm of shipbuilding excellence in the 1960's and 1970's, has now virtually abandoned the industry.

> Employment in Swedish yards has been reduced from over 30,000 in 1975 to 13,000 in December 1984. The decision was taken in December 1984 to close the Uddevalla Yard. Despite the fact that the Swedish shipyards are considered to be the most efficient in the world, subsidies from 1977 to 1984 had totalled $2 billion [Ref. 42: p. 39].

Few American corporations could justify sustained losses for very long to their shareholders with the lure of uncertain profits to be garnered a decade later.

3. Poor Customer Service Orientation

American commercial shipyards historically have been all but oblivious to the very real concerns of American shipowners.

Shipowners are faced with their own ominous array of problems. These include intense low cost foreign competition, high U.S. crew costs, and an ever increasing public concern for the environment. U.S. commercial shipbuilders have merely added another burden to the list. A recent statement by William P. Verdon, President, United Shipowners of America illustrates this point.

On the issue of vessel parity, we are in a unique position in that Operating Differential Subsidy (ODS)[4] operators today cannot build vessels that will allow them to compete in the world marketplace. They cannot build in the United States because of the excess costs without ODS and they cannot build foreign because of the current governmental regulations. Even if they had the wherewithal to build in the United States and even if they could find a banking institution willing to finance it on a 20-ship merchant marine company, they would be talking about a differential of over $1 billion.

Now, I am not specifically saying it is a billion or $900 million. I do not think the numbers are really important. What is important, Senator, is the relationship and the ratio of the difference. If the ships cost twice as much or 1.7 times as much, that fact is either one of those cases is a sure road map to bankruptcy. You just cannot do it [Ref. 5: p. 60].

While an in depth discussion of the problems of the U.S. shipowner will not be attempted in this thesis, Mr. Verdon's statement highlights two significant points:

1. High cost U.S. commercial shipbuilding has had a very definite impact on U.S. shipowners' desire to purchase abroad.
2. The high cost of building commercial ships in America has been a principal reason government legislators have continued to embrace protectionist legislation and refused to repeal the 1920 Jones Act. This act mandates that U.S. ships engaged in trade between U.S. ports be built in the United States.

4. Shipbuilding Technique

Shipbuilding technique represents another obstacle to U.S. competitiveness. Volumes have been written about the differences between shipbuilding production methods in the U.S. and those prevalent in Japan. However, in comparing the performance of a U.S. yard, Avondale, to a Japanese yard, Kawasaki Heavy Industries (KHI), Dr. Howard Bunch from NSRP made the following succinct observation:

The U.S. yard's poorest comparative performance is in the category of design-engineering-planning-mold loft. The difference is traceable to the standardization and modularization that permit a large portion of the design and engineering activities to be essentially the retrieval of the documentation from files [Ref. 46: p. 34].

Interestingly enough, Bunch indicates that the U.S. does not suffer a disadvantage with respect to incorporating computer technology into the design process, as the OTA study [Ref. 6: p. 99]. would seem to indicate.

Another example is the extent of integration of CAD/CAM being introduced into the production environment; Avondale was further advanced in this area than was KHI, Kobe [Ref. 46: p. 34].

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[4] ODS is a direct subsidy paid to U.S. flag operators to offset the high operating costs of U.S. flag ships when compared to foreign flag counterparts [Ref. 6: p. 223].

This thesis will not attempt to enumerate all areas in which U.S. shipbuilding technique is deficient. Chapter IV, Section B, (1.c.), offers a fair synopsis of shipbuilding techniques which Japan has employed to reduce overhead costs. U.S. shipbuilders are currently attempting to emulate many of these successful production methods.

5. Leadtime Management

The difficulty entailed in rapidly receiving components from suppliers is seen as another impediment to U.S. commercial shipbuilding competitiveness. Long leadtimes from suppliers have been a principal cause for the lengthy construction time required in American yards. In a recent article [Ref. 33: p. 255-257], Dr. Bunch describes the impact on the ship construction process of lengthy leadtimes. He compares a U.S yard (Avondale) to a Chinese yard (Hudong).

> In Red China, materials acquired within the Chinese domestic system either raw materials or finished goods are ordered at specified times during the year. The typical order months for shipyards are February and August; at those times purchasing agents indicate to a central organization their material needs for the next 6-12 months into the future. These requests are then forwarded to the specified supplier, or to a supplier of the central organization's choice if it is deemed necessary to make the supplier change [Ref. 33: p. 255].

Interestingly enough, Chinese shipyard procurement leadtimes are shorter than those in the U.S. even given the constraints imposed by an awkward, centrally controlled, system. "In only one instance, the electric generator, is the Hudong lead time period greater than that at Avondale" [Ref. 33: p. 256].

The reader is cautioned that while the inventory holding costs which accompany the shorter Chinese leadtimes are not considered, this example does make a statement about the level of customer service offered by American suppliers and the white collar support provided by American shipyard procurement departments.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis has attempted to examine the size and underlying reasons for productivity deficiencies in U.S. commercial shipbuilding.

Chapter II provided background information on the current status of the U.S. commercial shipbuilding industry with respect to other international shipbuilding nations. It depicts an industry which has reached its low point in the history of this nation.

Chapter III outlined the methodology to be used for productivity measurement. Four international shipbuilding studies [Ref. 7: pp. 1-32; Ref. 13: pp. 1-20; Ref. 14: pp. 44-66; and Ref. 15: pp. 539-567], were used extensively to make assumptions about cost structures prevalent in the U.S., Japan and Northern Europe during the 1980's. Wage data, gathered from the Bureau of Labor Statistics [Ref. 9: pp. 1-3 and Ref. 12: pp. 1-18] was used to extract labor productivity information measured in manhours worked per ship in the three respective areas. Similarly, steel prices obtained from the Metal Bulletin Handbook [Ref. 10: pp. 157-241 and Ref. 11: pp. 183-240] were used to extract material productivity information measured in metric tons of steel used per ship.

Chapter IV detailed the results of this analysis. It depicted U.S. labor productivity as exceeding that present in Europe but lagging far behind that prevalent in Japan. This analysis also revealed a U.S. commercial shipbuilding industry which suffers distinct disadvantages with respect to material and overhead productivity. Additionally, this chapter discussed at length how much of the apparent U.S. improvement in labor and material productivity can be explained by a U.S. dollar which decreased markedly against other international currencies.

Chapter V discussed in detail three formidable obstacles which continue to thwart U.S. competitive goals. The three obstacles described are fierce international competition, ineffective U.S. government policy, and the American business environment. A synopsis of important world commercial shipbuilders not discussed in the quantitative portion of this thesis was included in this chapter. Government policies seen as most detrimental to U.S. commercial shipbuilding were listed as:

- An absence of long term strategy
- A failure to promote a healthy mix of commercial and military ship construction

- A failure to recognize the impact that the absence of commercial shipbuilding has had on the U.S. industrial base
- A lack of commitment to research
- The federal budget deficit

Factors prevalent in the business sector seen as incompatible with a resurgence of the commercial shipbuilding sector were viewed to be:

- The absence of profitability to attract investors to U.S. commercial shipbuilding
- A short term corporate outlook
- Poor customer service orientation
- Inefficient shipbuilding technique
- Ineffective leadtime management

B. CONCLUSIONS

The central conclusion of this thesis is that the U.S. commercial shipbuilding industry continues to face significant productivity problems with respect to its international competitors.

While U.S. hourly wage rates are approximately equal to those earned in Japan, U.S. labor productivity is markedly lower. The U.S. does, however, enjoy a slight labor productivity advantage over Northern European shipbuilders. The labor productivity advantage enjoyed over Northern European shipbuilders, however, seems less significant when considering that a number of low cost, technologically advanced shipbuilders, such as China, Korea, Brazil, and several eastern European nations seemed poised to flex their industrial muscle upon the international shipbuilding scene.

Material productivity in the United States, while improving, lags behind that achieved in Japan and Europe by a significant margin. Efficient shipbuilding practices such as design and material use standardization, zone outfitting, process lane operation, and just-in-time inventory management have been key ingredients in making Japan the world leader with respect to material productivity.

U.S. overhead productivity suffers for two principal reasons:

1. The high cost of capital tends to discourage long term investment in plant and equipment. This failure to keep pace with the latest forms of industrial technology continues to have an adverse effect on labor and material productivity.
2. The small U.S. orderbook makes it extremely difficult for U.S. commercial shipbuilders to take advantage of the economies of scale which accrue with larger serial production operation.

A second, perhaps more important conclusion, is that U.S. commercial shipbuilders face a tough, uphill battle for survival. Stiff competition from abroad will continue to be a chief obstacle. A U.S. government policy with no long term strategy and an enormous deficit have not proved helpful to the industry. Corporate investors are likely to steer clear of commercial shipbuilding in this country until productivity and profitability improve.

C. RECOMMENDATIONS

Several options can be pursued to assist U.S. commercial shipbuilders to achieve the competitive goals defined in Chapter III. These are:

1. Transplant Shipyards

U.S. and Japanese cooperation has been employed in other industries to the advantage of both partners. The automotive industry offers several such examples. There are currently eight transplant automobile factories in the U.S. Toyota which builds some of its Corolla subcompacts at its joint venture factory with GM in Fremont, California, plans to build a second plant in the U.S. sometime in the near future [Ref. 47: pp. A3 and A6].

Shipbuilding seems ideally suited to a transplant arrangement. Japan offers a wealth of capital, experience, and management expertise and could anticipate profits in excess of those which U.S. shipbuilders are capable of earning by virtue of their more efficient shipbuilding technique. The U.S. offers adequate facilities and an increasingly productive workforce. The aging U.S. flag fleet would profit by obtaining sorely needed replacement tonnage at lower cost. U.S. shipping consumers would also benefit by the achievement of lower cost.

Some groundwork has already been laid for such an endeavor. Scholars from the National Shipbuilding Research Program (NSRP) have worked with Japanese shipbuilders for more than a decade on efforts to import Japanese shipbuilding expertise and incorporate it into the U.S. shipbuilding process [Ref. 27: pp. 104-114].

A recent comment by John Stocker, President of the Shipbuilders' Council of America, indicates that foreign interest in U.S. shipyards is not just a theoretical proposition.

> I have had foreign shipyard executives who are interested in potential joint ventures with U.S. yards come to me and say one of the reasons they are interested is because of the fact that the United States does offer, by comparison to their own countries, low labor cost, and I think that is a fairly fundamental shift that is not well-recognized here in Washington [Ref. 5: p. 49].

2. Greater Military Involvement in Commercial Shipbuilding

With a $288.3 billion dollar budget authorization for 1991 [Ref. 48: p. 1], DOD would appear to be a deep-pocketed alternative for financing a resurgence of commercial shipbuilding in this country. The Navy's current domination of the shipbuilding orderbook as well as the importance of the shipbuilding industrial base to the Navy provide additional rationales for linking commercial and military shipbuilding.

Perhaps the most significant argument in favor of greater military involvement in commercial shipbuilding is DOD's notably deficient military sealift capability. Recent experience related to Operation Desert Shield underscores this point.

> Vice Admiral Francis R. Donovan, Commander of the Military Sealift Command (MSC) told the House Merchant Marine subcommittee during hearings that U.S. flag surge sealift was inadequate to meet all DOD requirements and the charter of foreign flag breakbulk and roll-on/roll-off (ro-ro) ships was necessary [Ref. 49: pp. 1-3].

Additionally, U.S. flag operations were unable to rapidly provide the requisite number of breakbulk ships needed for Desert Shield [Ref. 49: pp. 1-3].

Another interesting aspect of Operation Desert Shield has been the inability to deploy Ready Reserve Force (RRF) ships on schedule which were supposed to have been deployable within a five day period. This inability was caused at least in part because of the poor material condition of these ships.

Seemingly, such deficiencies would translate into increased business for U.S. commercial shipyards. However, DOD has been reluctant to spend money on improving military sealift capability. Nearly $600 million dollars was appropriated in the FY 1990 budget for military sealift but $217.2 million of this sum was reprogrammed to help pay for other defense account shortfalls. DOD refused to release the remaining $375 million dollars for several months [Ref. 45: pp. 1-3 and Ref. 50: pp. 1-3].

A year earlier, Everett Pyatt, then Assistant Secretary of the Navy for Shipbuilding and Logistics, labeled the Military Sealift Program as in "reasonably good health" [Ref. 5: p. 24]. His statement, which follows, summarized the Navy's position on commercial shipbuilding.

> While we sympathize with the currently depressed industry and we continue to support the need for an adequate shipyard industry, we cannot support industrial capacity that is excess to our needs [Ref. 5: pp. 19-20].

DOD's reluctance to participate in improvement to military sealift capability seems to be motivated by two factors:

1. DOD has itself been forced into austerity measures which threaten the number of weapon systems which can be purchased.

2. Congress endorses additional military sealift capability. Given the contrarian nature of political decision making, Congressional support for additional military sealift capability frees DOD to pursue acceptance of other weapons systems with Congress. Apparently, DOD assumes that resourceful lawmakers will find a way to fund military sealift enhancements regardless of the wishes of defense department officials.

The political intrigue notwithstanding, one thing is clear: advocates of commercial shipbuilding will continue to eye DOD's budget as a potential source of funds. Indeed, by forfeiting one SSN-21 submarine with a price tag of $1.4 billion dollars, the U.S. could purchase forty-six 60,000/65,000 DWT bulk and combined carriers at the prevailing world price of $30 million [Ref. 48: p. 1 and Ref. 19: p. 51].

3. End Subsidies Abroad

One story currently unfolding in the policy arena, is the Shipbuilders Council of America (SCA) filing of a Section 301 petition under the amended U.S. Trade Act of 1974. This petition asks the U.S. Trade Representative to negotiate an end to domestic shipbuilding subsidies in various nations. The U.S. Trade Representative (USTR) Carla Hills, despite aggressive pursuit of the issue internationally, has been largely unsuccessessful in getting the nations involved to sign an agreement which includes sanctions against those nations that violate the proposed anti-subsidy agreement [Ref. 51: p. 2]. Additionally, bipartisan legislation has been introduced which would levy a "special assessment on subsidized foreign ships entering U.S. ports" [Ref. 52: p. 2].

Influential members of Congress, including House Chairman of the Ways and Means Committee, Dan Rostenkowski (D-Ill.), have told the USTR that the most recent deadline in the process, 14 December 1990, must be met or the "U.S. government would have to evaluate other options to ensure that the subsidies do not continue to harm the U.S. shipbuilding industry" [Ref. 53: p. 3].

Such legislation poses some interesting policy questions. Is the U.S. really prepared to engage in a trade war with countries that have traditionally been considered its allies in order to protect its commercial shipbuilding interests? Is the trade petition issue really a backdoor mechanism for re-subsidizing U.S. shipyards? Should the USTR fail to make progress with the international shipbuilding community and Congress fail to take action against nations subsidizing their shipbuilding programs, it would appear that the SCA would have a compelling argument for obtaining a modern version of Construction Differential Subsidies.

The attempt to end subsidies abroad comprises a cleverly crafted strategy. It appeals to American's sense of fair play, yet may in itself be a veiled request for domestic subsidies. However, this strategy has two primary problems:

1. It is unlikely that the USTR can get the international community to agree to end subsidies [Ref. 54: p. 3].
2. If the playing field were indeed leveled, it is unlikely given other data presented in this thesis that U.S. commercial shipbuilders would fare very well. Even SCA president John Stocker concedes, "We are not ten feet tall" [Ref. 5: p. 49].

4. Pursue Environmental Issues

Another issue which offers a potential springboard of opportunity for U.S. commercial shipbuilders is the environment. "Black ooze is becoming a more common sight on our beaches than suntan lotion" [Ref. 55: p. 1].

The aftermath of the Exxon Valdez mishap, the Mega Borg fire/oil spill and other several well publicized incidents is that the American public has grown increasingly less tolerant of tanker spills which threaten the environment. In response to public pressure, during July 1990, "Congress agreed to require double hulls for new tankers and to phase them in for most existing ships by 2010" [Ref. 56: p. A-14].

Such legislation offers the promise of more commercial business for American shipyards. Some have suggested that U.S. yards have the capability to compete for export orders on "radically different product-environmentally-sensitive, double hull tankers" [Ref. 57: pp. 1-2]. While the recently passed double-hull legislation may have the desirable impact of accelerating replacement of Jones Act tonnage, it is difficult to believe that other nations will not maintain some productive edge in constructing double hull technology ships.

5. Shipyard Recovery Program

The SCA has its own detailed plan for reversing the decline of the shipbuilding industry in this country. It is called the Shipyard Recovery Program, and it is an amalgam of several alternatives listed previously. This proposal includes [Ref. 5: pp. 55-59]:

1. Putting an end to foreign shipbuilding subsidies
2. Government support for commercial research and development
3. The construction of Military Sealift Tankers. Such construction is to serve as a bridge between the current military orientation of U.S. yards to a more commercially-based U.S. industry.
4. The design and construction of a fast Monohull Sealift Ship

5. Funding for a fast sealift ship of the future.

The plan also encourages productivity enhancements including:

- Increased investment in new capital
- Greater cooperation between labor and management
- Increased worker training
- Employment of more productive shipbuilding technique.

While the plan has considerable merit, principal problem areas are:

1. The uncertainty entailed in getting foreign nations to end their shipbuilding subsidy programs
2. DOD's reluctance to fund enhancements to military sealift capability
3. A lack of specifics on achievement of productivity improvement.

Even if such a plan were adopted, a demanding mechanism for monitoring its execution would be essential to ensure that mistakes made during the CDS era were not repeated.

6. Final Note

The future of America's commercial shipbuilding industry is murky. The foregoing section has detailed a number of alternatives for improvement. An effort has been made to discuss the advantages and disadvantages of each option. However, one thing is certain. If no aggressive action is taken, commercial shipbuilding in this country faces almost certain extinction. It would be a national tragedy for a once proud industry to face such an ignoble demise. Dr. Paula J. Pettavino poignantly summarized the plight of shipbuilding in this country,

> The current American maritime structure is like a beautiful flower without a substantial root system. If we do not strengthen the roots, the flower is in danger of perishing [Ref. 58: p. 55].

APPENDIX A. INTERNATIONAL WAGES

All dollar and local currency wages and percentages with the exceptions contained in the two notes below for 1989 were obtained from Bureau of Labor Statistics (BLS) publications [Ref. 9: pp. 1-3]. The methodology used for compiling this data is identical to that used by BLS in [Ref. 9: pp. 1-3] and the data is identical to BLS data to three decimal places. Data is subject to the remarks and limitations listed at the end of this appendix. The second column lists hourly wages in U. S. dollars. The third column lists hourly wages in units of local currency and is readily obtained by multiplying the data in the second column by the applicable BLS currency conversion factor contained in Appendix B. The fourth column is a percentage ratio of foreign wages in dollars to U.S. wages in dollars (i.e., in 1981 Belgian dollar wages were 108.869 % of U.S. dollar wages).

A. EXCEPTIONS

1. Note One

In 1989, wages measured in U.S. dollars for Belgium and the Netherlands were not available from BLS. Consequently, 1988 dollar wages were used as the basis for 1989 information about these two countries. 1989 conversion factors and U.S. wages for 1989 were used to derive data in columns 3 and 4 for this year. (Dollar wages (Column 2) in Belgium and the Netherlands are the same during 1988 and 1989. The information in columns three and four for 1989 in these two countries was "forced" using actual 1989 local currency conversion factors and actual 1989 U.S. dollar wages.)

2. Note Two

Data was not available from BLS to measure Spanish wages in U.S. dollars for 1989. Since Southern European dollar wages in Italy and Great Britain rose modestly from 1988 to 1989, Spanish dollar wages were assumed to follow the same pattern. The 51 cent raise in Italy from 1988 to 1989 and the 17 cent raise in the United Kingdom from 1988 to 1989 were averaged and a 34 cent raise was applied to 1988 Spanish dollar wages to obtain 1989 Spanish dollar wages. The 1989 peseta to dollar conversion factor and U.S. wages for 1989 were used together with the reconstructed Spanish dollar wage data to derive the numbers in columns 3 and 4 for this year. Spanish dollar wages are 34 cents higher in 1989 that they were in 1988. The information in columns 3 and 4 for 1989 was "forced" using an actual 1989 peseta-to-dollar currency conversion factor and actual 1989 U.S. dollar wages.)

BELGIUM

Year	$	LC	% U.S.
1981	13.38	495.461	108.869
1982	10.91	499.460	80.935
1983	10.35	529.092	74.946
1984	9.78	564.795	68.825
1985	10.17	603.488	69.801
1986	13.79	615.861	94.001
1987	16.75	625.780	117.215
1988	16.78	617.168	117.097
1989	16.78	610.959	113.609

DENMARK

Year	$	LC	% U.S.
1981	10.15	72.085	82.587
1982	9.56	79.769	70.920
1983	9.26	84.710	67.053
1984	8.46	87.561	59.536
1985	8.59	91.054	58.957
1986	11.70	94.711	79.755
1987	15.55	106.486	108.817
1988	16.99	114.530	118.562
1989	16.23	118.820	109.885

FINLAND

Year	$	LC	% U.S.
1981	8.91	38.4734	72.498
1982	8.79	42.2711	65.208
1983	8.42	46.8489	60.970
1984	8.79	52.7488	61.858
1985	9.14	56.6406	62.732
1986	12.89	65.3781	87.866
1987	15.67	69.0107	109.657
1988	17.73	74.3419	123.726
1989	19.66	84.4593	133.108

FRANCE

Year	$	LC	% U.S.
1981	8.92	48.2483	72.579
1982	8.95	58.8820	66.395
1983	8.97	68.3514	64.953
1984	8.86	77.4009	62.350
1985	8.93	80.1914	61.290
1986	11.66	80.7571	79.482
1987	13.97	83.9876	97.761
1988	14.51	86.4651	101.256
1989	14.09	89.8942	95.396

WEST GERMANY

Year	$	LC	% U.S.
1981	11.67	26.3042	94.955
1982	11.60	28.1648	86.053
1983	11.65	29.7541	84.359
1984	10.68	30.3846	75.158
1985	11.01	32.3914	75.566
1986	15.19	32.9623	103.545
1987	19.39	34.8632	135.689
1988	20.89	36.7037	145.778
1989	20.16	37.9209	136.493

NETHERLANDS

Year	$	LC	% U.S.
1981	10.22	25.4274	83.157
1982	10.02	26.7734	74.332
1983	9.57	27.3128	69.298
1984	8.63	27.6850	60.732
1985	8.87	29.4306	60.878
1986	12.68	31.0406	86.435
1987	15.60	31.6056	109.167
1988	15.87	31.3909	110.747
1989	15.87	33.6761	107.448

NORWAY

Year	$	LC	% U.S.
1981	11.72	67.132	95.362
1982	11.59	74.837	85.979
1983	11.16	81.479	80.811
1984	10.87	88.699	76.495
1985	11.25	96.671	77.213
1986	14.13	104.534	96.319
1987	18.43	124.237	128.971
1988	19.88	129.697	138.730
1989	19.63	135.702	132.904

ITALY

Year	$	LC	% U.S.
1981	8.47	9579.6	68.918
1982	8.23	11143.4	61.053
1983	8.48	12881.1	61.405
1984	7.98	14012.9	56.158
1985	8.35	15940.1	57.310
1986	11.23	16743.9	76.551
1987	13.83	17937.5	96.781
1988	14.59	18996.2	101.814
1989	15.10	20717.2	102.234

SPAIN

Year	S	LC	% U.S.
1981	7.03	646.76	57.2009
1982	6.69	736.57	49.6291
1983	5.69	816.51	41.2020
1984	5.35	860.28	37.6495
1985	5.54	941.80	38.0233
1986	7.74	1083.60	52.7607
1987	9.54	1178.19	66.7599
1988	10.85	1264.02	75.7153
1989	11.19	1324.90	75.7617

UNITED KINGDOM

Year	S	LC	% U.S.
1981	7.30	3.13900	59.3979
1982	6.97	3.98754	51.7062
1983	6.47	4.26826	46.8501
1984	6.11	4.57150	42.9979
1985	6.37	4.91000	43.7200
1986	7.78	5.30051	53.0334
1987	8.92	5.43941	62.4212
1988	9.89	5.55225	69.0160
1989	10.06	6.14062	68.1110

UNITED STATES

Year	$	LC	% U.S.
1981	12.29	12.2900	100
1982	13.48	13.4800	100
1983	13.81	13.8100	100
1984	14.21	14.2100	100
1985	14.57	14.5700	100
1986	14.67	14.6700	100
1987	14.29	14.2900	100
1988	14.33	14.3300	100
1989	14.77	14.7700	100

JAPAN

Year	$	LC	% U.S.
1981	7.79	1714.58	63.385
1982	6.98	1738.72	51.780
1983	7.70	1829.52	55.757
1984	7.80	1851.72	54.891
1985	8.12	1936.62	55.731
1986	11.37	1914.71	77.505
1987	12.57	1817.62	87.964
1988	14.83	1901.21	103.489
1989	14.67	2025.93	99.323

KOREA

Year	$	LC	% U.S.
1981	2.06	1403	16.762
1982	2.13	1556	15.801
1983	2.21	1717	16.003
1984	2.19	1765	15.412
1985	2.30	1999	15.786
1986	2.49	2194	16.973
1987	2.99	2456	20.924
1988	4.40	3217	30.705
1989	6.35	4263	42.993

REMARKS AND LIMITATIONS

The accompanying tables present international comparisons of hourly compensation costs, hourly direct pay, and pay for time worked for production workers in manufacturing in (various) countries or areas. The total compensation measures are prepared by the Bureau of Labor Statistics in order to provide a better basis for assessing international differences in employer labor costs. Comparisons based on the more readily available average earnings statistics published by many countries can be very misleading. National definitions of average earnings differ considerably; average earnings do not include all items of labor compensation; and the omitted items of compensation frequently represent a large proportion of total compensation. The total direct pay and pay for time worked measures are prepared to provide a comparable basis for analyzing the main components of total compensation.

The compensation and other pay measures are computed in national currency units and are converted into U.S. dollars at prevailing commercial market currency exchange rates. Hourly compensation converted into U.S. dollars at commercial market exchange rates is an appropriate measure for comparing levels of employer labor costs. It does not indicate relative living standards of workers or the purchasing power of their income. Prices of goods and servicers vary greatly among countries, and commercial market exchange rates are not reliable indicators of relative differences in prices.

DEFINITIONS

Hourly compensation is defined as (1) all payments made directly to the work, before payroll deductions of any kind, and (2) employer social insurance expenditures--that is, expenditures for legally required insurance programs and contractual and private benefit plans. In addition, for some countries, compensation is adjusted for other taxes on payrolls or employment (or reduced to reflect subsidies), even if they are not for the direct benefit of workers, because such taxes are regarded as labor costs. However, hourly compensation does not include all items of labor costs. The costs of recruitment, employee training, and plant facilities and services--such as cafeterias and medical clinics--are not covered because data are not available for most countries. The labor costs not covered account for no more that 4 percent of total labor costs in any country for which data are available. For consistency, compensation is measured on an hours-worked basis for every country.

Hourly direct pay includes pay for time worked (basic time and piece rates plus overtime premiums, shift differentials, other premiums and bonuses paid regularly each pay period, and cost-of-living adjustments) and other direct pay--pay for time not worked (vacations, holidays, and other leave, except sick leave), seasonal or irregular bonuses and other special payments, selected social allowances, and the cost of payments in kind, before deductions of any kind. Direct pay is also measured on an hours-worked basis for every country.

Pay for time worked includes only basic time and piece rates, overtime premiums, shift differentials, other premiums and bonuses paid regularly each pay period, and cost-of-living adjustments (COLA's). Pay for time worked is measured on an hours-worked basis for every country.

Production workers generally include those employees who are engaged in fabricating, assembly, and related activities; material handling, warehousing, and shipping; maintenance and repair; janitorial and guard services; auxiliary production (e.g., powerplants); and recordkeeping and other services closely related to the above activities. Working supervisors, are generally included; apprentices and other trainees are generally excluded.

METHODS

Total compensation is computed by adjusting each country's average earnings series for items of direct pay not included in earnings and for employer expenditures for legally required insurance, contractual and private benefit plans, and average earnings for items of direct pay not included in earnings. Pay for time worked is measured by adjusting average earnings, where necessary, to eliminate other items of direct pay. For the United States and other countries that measure earnings on an hours-paid basis, the figures are also adjusted in order to approximate compensation or pay per hour worked.

Earnings statistics are obtained from surveys of employment, hours, and earnings or from surveys or censuses of manufacturers.

Adjustment factors are obtained primarily from periodic labor cost surveys and interpolated or projected to nonsurvey years on the basis of other available information; or they are obtained from surveys of manufacturers or reports on social security and fringe benefits systems. For some countries, data are not available to compute pay for time worked.

The statistics are also adjusted, where necessary, to account for major differences in worker coverage; differences in industrial classification systems; and changes over time in survey coverage, sample benchmarks, or frequency of surveys. Special estimation procedures have been used for some countries because of incomplete data.

Hourly compensation costs, hourly direct pay, and pay for time worked are converted to U.S. dollars using the average daily exchange rate for the reference period. Changes in hourly compensation in U.S. dollars from one period to another are therefore affected by changes in currency exchange rates as well as by changes in compensation. The exchange rates used are prevailing commercial market exchange rates as published by either the U.S. Federal Reserve Board or the International Monetary Fund.

DATA LIMITATIONS

Because compensation and direct pay (and, for some countries, pay for time worked) are partly estimated, the statistics should not be considered as precise measures of comparative compensation costs. In addition, the figures are subject to revision as the results of new labor cost surveys or other data used to estimate compensation costs become available.

The comparative level figures in these tables are averages for all manufacturing industries and are not necessarily representative of all component industries. In the United States and some other countries, such as Japan, differentials in hourly compensation costs levels by industry are quite wide. In contrast, other countries, such as Germany and Sweden, have narrow differentials.

LABOR COSTS VERSUS LABOR INCOME

The hourly compensation figures in U.S. dollars shown in the tables provide comparative measures of employer labor costs; they do not provide intercountry comparisons of the purchasing power of worker incomes. Prices of goods and services vary greatly among countries, and the commercial market exchange rates used to compare employer labor costs are not reliable indicators of relative differences in prices. Purchasing-power-parity exchange rates--that is, the number of foreign currency units required to buy goods and services equivalent to what can be purchased with one unit of U.S. or other base-country currency--must be used for meaningful international comparisons of the relative purchasing power of worker incomes [Ref. 12: pp. 2-5].

APPENDIX B. CURRENCY CONVERSION FACTORS

The data obtained in this appendix was extracted from Bureau of Labor Statistics (BLS) publications [Ref. 12: pp. 10-18]. Listed are the yearly average exchange rates between units of foreign currencies and the U.S. dollar during the period of this study. The names of the relevant foreign currencies are listed below:

1. Northern Europe

- Belgium: Belgian franc
- Denmark: krone
- Finland: markha
- France: franc
- Germany: deutschemark
- Norway: krone
- Netherlands: guilder
- Sweden: krona

2. Southern Europe

- Italy: lira
- Spain: peseta
- United Kingdom: pound

3. Others

- Japan: yen
- Korea. won
- United States: dollar

YEAR	BELGIUM	DENMARK	FINLAND	FRANCE	FRG	NETHERLANDS
1981	37.0300	7.1020	4.31800	5.40900	2.25400	2.48800
1982	45.7800	8.3440	4.80900	6.57900	2.42800	2.67200
1983	51.1200	9.1480	5.56400	7.62000	2.55400	2.85400
1984	57.7500	10.3500	6.00100	8.73600	2.84500	3.20800
1985	59.3400	10.6000	6.19700	8.98000	2.94200	3.31800
1986	44.6600	8.0950	5.07200	6.92600	2.17000	2.44800
1987	37.3600	6.8480	4.40400	6.01200	1.79800	2.02600
1988	36.7800	6.7410	4.19300	5.95900	1.75700	1.97800
1989	36.4100	7.3210	4.29600	6.38000	1.88100	2.12200

YEAR	NORWAY	ITALY	SPAIN	UK	USA	JAPAN	KOREA
1981	5.72800	1131	92.0	0.430000	1	220.1	681.0
1982	6.45700	1354	110.1	0.572100	1	249.1	731.1
1983	7.30100	1519	143.5	0.659700	1	237.6	775.8
1984	8.16000	1756	160.8	0.748200	1	237.4	806.0
1985	8.59300	1909	170.0	0.770800	1	238.5	870.0
1986	7.39800	1491	140.0	0.681300	1	168.4	881.4
1987	6.74100	1297	123.5	0.609800	1	144.6	822.6
1988	6.52400	1302	116.5	0.561400	1	128.2	731.5
1989	6.91300	1372	118.4	0.610400	1	138.1	671.5

YEAR	SWEDEN
1981	5.035
1982	6.284
1983	7.672
1984	8.271
1985	8.603
1986	7.127
1987	6.347
1988	6.137
1989	6.456

APPENDIX C. STEEL PRICES

International steel prices for the years 1981-1989 for heavy plate steel were obtained from yearly editions of the Metal Bulletin Handbook [Ref. 10: pp. 157-241] and its successor, Metal Bulletin's Prices and Data Book [Ref. 11: pp. 183-240]. The unit used was the metric ton. Prices listed in this appendix for each country are comprised of two entries per year. The first price listed is the price in U.S. dollars per metric ton rounded to the nearest dollar. The second caption lists the prices per ton in units of local currency. This figure was obtained by applying the appropriate currency conversion factor shown in Appendix B to the dollar figure in the first column.

Since U.S. prices were listed in hundreds of lbs. of steel, a conversion factor of 20.3208 was used to convert the price per 100 lbs. into the price per metric ton. Chapter II contains additional remarks regarding the methodology used to obtain steel prices. Following the listing of the data used in this thesis, the special procedures used to reconstruct steel prices for Norway and Spain are discussed.

YEAR	BELGIUM		DENMARK	
	$	LC	$	LC
1981	331	12256.9	299	2123.50
1982	344	15748.3	340	2836.96
1983	332	16971.8	322	2945.66
1984	296	17094.0	296	3063.60
1985	288	17089.9	295	3127.00
1986	396	17685.4	386	3124.67
1987	482	18007.5	456	3122.69
1988	489	17985.4	464	3127.82
1989	494	17986.5	430	3148.03

YEAR	FINLAND		FRANCE	
	$	LC	$	LC
1981	335	1446.53	327	1768.74
1982	347	1668.72	356	2342.12
1983	306	1702.58	335	2552.70
1984	284	1704.28	302	2638.27
1985	275	1704.17	294	2640.12
1986	382	1937.50	395	2735.77
1987	439	1933.36	462	2777.54
1988	452	1895.24	480	2860.32
1989	450	1933.20	454	2896.52

YEAR	GERMANY(FRG)		NETHERLANDS	
	$	LC	$	LC
1981	357	804.678	309	768.79
1982	371	900.788	364	972.61
1983	366	934.764	347	990.34
1984	328	933.160	308	988.06
1985	318	935.556	292	968.86
1986	431	935.270	408	998.78
1987	528	949.344	499	1010.97
1988	541	950.537	511	1010.76
1989	505	949.905	476	1010.07

YEAR	NORWAY		ITALY	
	$	LC	$	LC
1981	292	1672.58	346	391326
1982	291	1878.99	368	498272
1983	290	2117.29	357	542283
1984	314	2562.24	312	547872
1985	302	2595.09	264	503976
1986	365	2700.27	405	603855
1987	402	2709.88	484	627748
1988	457	2981.47	482	627564
1989	466	3221.46	477	654444

YEAR	SPAIN		UNITED KINGDOM	
	$	LC	$	LC
1981	357	32844.0	423	181.890
1982	357	39305.7	358	204.812
1983	334	47929.0	315	207.805
1984	302	48561.6	296	221.467
1985	290	49300.0	312	240.490
1986	449	62860.0	375	255.487
1987	474	58539.0	424	258.555
1988	495	57667.5	463	259.928
1989	483	57187.2	446	272.238

YEAR	UNITED STATES		JAPAN	
	$	LC	$	LC
1981	464	464	370	81436.9
1982	493	493	313	77968.2
1983	517	517	314	74606.4
1984	498	498	316	75018.4
1985	498	498	302	72027.0
1986	395	395	357	60118.8
1987	387	387	422	61021.2
1988	462	462	517	66279.4
1989	478	478	496	68497.6

A. NORWEGIAN STEEL PRICE COMPUTATION (1981-1989)

Norwegian steel prices for 1981-1989 were obtained by, first, converting Swedish steel prices in Swedish krona to U.S. dollars using the appropriate yearly krona to dollar conversion ratio contained in Appendix B and extracted from [Ref. 12: pp. 10-18]. After conversion, a two percent transportation charge was added to the Swedish price to obtain an approximation of the Norwegian price. Norwegian prices were rounded to the nearest U.S. dollar. This methodology is shown in Table 29 on page 95.

B. SPANISH STEEL PRICE COMPUTATION (1981-1985)

A simple arithmetic average in dollars of four European countries, two Northern European, Belgium and France, and two Southern European: Italy and the United Kingdom were used to compute Spanish steel prices from 1981 through 1989. The results are shown in Table 30 on page 95.

Spanish steel prices for the period 1986-1989 were obtained from the Metal Bulletin Price [Ref. 10: pp. 157-241] and Data Book [Ref. 11: pp. 183-240] and are listed above in the same format as provided for other countries in Appendix C.

Table 29. NORWEGIAN STEEL PRICE COMPUTATION: 1981-1989

Year	Swedish Steel Price	Swedish Krona to US$	Steel Price in $	Transportation Charge	Norwegian Steel Price
1981	1440	5.035	285.99	.02	292
1982	1790	6.284	284.85	.02	291
1983	2180	7.672	284.15	.02	290
1984	2550	8.271	308.31	.02	314
1985	2550	8.603	296.41	.02	302
1986	2550	7.127	357.79	.02	365
1987	2550	6.347	393.89	.02	402
1988	2750	6.137	448.10	.02	457
1989	2950	6.456	456.94	.02	466

Table 30. SPANISH STEEL PRICE COMPUTATION: 1981-1985

Year	BELGIUM	FRANCE	ITALY	U.K.	SPAIN
1981	330.78	326.92	346.23	423.26	357
1982	344.40	356.44	367.62	358.32	357
1983	331.90	335.46	357.03	315.80	334
1984	296.10	301.91	311.69	296.17	302
1985	288.16	293.71	263.52	312.92	290

APPENDIX D. NEWBUILDING PRICES.

The Minitab (a statistical software package) output contained in this appendix details the methodology used to obtain the newbuilding prices used in Figure 1 and Column 1 of Table 14. Prices were obtained from [Ref. 19: p. 61]. Data on deadweight tonnage was taken from [Ref. 20: pp. 684-687].

Prices were divided into two categories. One category consisted of four weight classes of tankers. The second category consisted of four different classes of bulk and combined carriers.

Ships were also considered to belong to one of two different types of tonnage. Tankers comprised one type; bulk and combined carriers comprised the other.

The arithmetic weight that a given price category contributed to total composite ship price changed from year to year. The change in this weight was based on the ratio of the amount of deadweight tonnage ordered for that ship type to the overall world tonnage ordered for that year.

The data reflects the change in ship buyer preference from bulk and combined carriage tonnage during the period 1981 to 1986 to tanker tonnage during the 1987-1989 timeframe.

```
MTB > read 'newbuild data' c1-c14
        9 ROWS READ
```

ROW	YEAR	30-35 tk	>80 tk	>135 tk	>280tk	40 b&c	60-65b&c	140 b&c
1	81	30	35	43	70	19	26	40
2	82	19	25	30	50	16	19	29
3	83	18	23	29	47	15	18	27
4	84	15	21	27	40	14	16	22

ROW	100 obo	tot tons	tot tk	blktons	con tons	dry tons
1	48	59	19.3	33.5	2.0	3.6
2	32	57	15.0	32.0	4.1	4.1
3	30	49	11.5	27.0	3.1	4.2
4	26	56	11.9	34.0	3.9	3.9

MTB > print c1-c/

ROW	YEAR	30-35 tk	>80 tk	>135 tk	>280tk	40 b&c	60-65b&c
1	81	30	35	43	70	19	26
2	82	19	25	30	50	16	19
3	83	18	23	29	47	15	18
4	84	15	21	27	40	14	16
5	85	13	19	25	37	11	14
6	86	15	23	30	45	12	17
7	87	17	30	34	48	18	20
8	88	24	34	45	73	21	26
9	89	28	43	52	82	25	30

```
MTB > print c8-c14

ROW   140 b&c  100 obo  tot tons  tot tk  blktons  con tons  dry tons

  1      40       48       59      19.3     33.5      2.0       3.6
  2      29       32       57      15.0     32.0      4.1       4.1
  3      27       30       49      11.5     27.0      3.1       4.2
  4      22       26       56      11.9     34.0      3.9       3.9
  5      21       22       52      14.0     29.0      3.7       2.9
  6      23       28       43      12.9     23.0      3.2       2.5
  7      30       33       33      14.9     12.0      2.0       2.0
  8      38       45       35      19.3     10.5      3.0       1.7
  9      44       54       37      20.0     12.0      2.9       2.1

MTB > let c15 = (c2+c3+c4+c5)/4
MTB > name c15 = 'avgtkprc'
MTB > let c16 = (c6+c7+c8+c9)/4
MTB > name c16 = 'avgbcprc'
MTB > let c17 = (c11*c15)/c10
MTB > name c17 = 'tk wght'
MTB > let c18 = c12+c13+c14
MTB > name c18 = 'tl bk tn'
MTB > let c19 = (c16*c18)/c10
MTB > name c19 = 'bk wght'
MTB > let c20 = c17+c19
MTB > name c20 = 'ship prc'
MTB > print c1 c15-c20
```

ROW	YEAR	avgtkprc	avgbcprc	tk wght	tl bk tn	bk wght	ship prc
1	81	44.5000	33.2500	14.5568	39.1	22.0352	36.5919
2	82	31.0000	24.0000	8.1579	40.2	16.9263	25.0842
3	83	29.2500	22.5000	6.8648	34.3	15.7500	22.6148
4	84	25.7500	19.5000	5.4719	41.8	14.5553	20.0272
5	85	23.5000	17.0000	6.3269	35.6	11.6385	17.9654
6	86	28.2500	20.0000	8.4750	28.7	13.3488	21.8238
7	87	32.2500	25.2500	14.5614	16.0	12.2424	26.8038
8	88	44.0000	32.5000	24.2628	15.2	14.1143	38.3771
9	89	51.2500	38.2500	27.7027	17.0	17.5743	45.2770

KEY TO COLUMN NAME ABBREVIATIONS

- C1 = Year
- C2 = 30-35tk: 30,000-35,000 DWT tanker price in millions($)
- C3 = >80tk: 80,000 DWT tanker price in millions($)
- C4 = > 135tk: 135,000 DWT tanker price in millions($)
- C5 = >280tk: 280,000 DWT tanker price in millions($)
- C6 = 40b&c: 40,000 DWT bulk & combined carrier price in millions($)
- C7 = 60-65b&c: 60,000-65,000 DWT bulk & combined carrier price in millions($)
- C8 = 140 b&c: 140,000 DWT bulk & combined carrier price in millions($)
- C9 = 100 OBO: 100,000 DWT bulk & combined carrier price in millions($)
- C10 = Tot tons: Total world tonnage on order (in millions of DWT)
- C11 = Tot tk: Total tanker tonnage on order (in millions of DWT)
- C12 = Blk tons: Total bulk tonnage on order (in millions of DWT)
- C13 = Con tons: Total container tonnage on order (in millions of DWT)
- C14 = Dry tons: Total dry tonnage on order (in millions of DWT)
- C15 = Avtkprc: Average tanker price in millions($)
- C16 = Avbcprc: Average bulk & combined ship price in millions($)
- C17 = tk wght: Contribution of tanker price to newbuilding price in millions($)
- C18 = tl bk tn: Total bulk, container and dry tonnage on order (in millions of DWT)
- C19 = Bk wght: Contribution of bulk, container and dry price to newbuilding price in millions($)
- C20 = Ship Price: Composite newbuilding price in millions($)

APPENDIX E. PRODUCTION TOTALS

This appendix contains commercial ship production totals by country measured in gross tons for the years 1981 through 1989. Data was obtained from [Ref. 3: p.3], [Ref. 23: pp. 76-77, Ref. 24: pp. 28-60, Ref. 25: pp. 1-2, and Ref. 26: pp. 1-2]. Since data contained in [Ref. 24: pp. 28-60] for the years 1984-1986 was measured in DWT instead of GT, the table contained in [Ref. 1: p. 388] was used to convert deadweight tonnage to approximate gross tonnage.

YEAR	BELGIUM	DENMARK	FINLAND	FRANCE
1981	155251	352220	216507	501519
1982	147797	451367	270610	264810
1983	299809	443861	259621	307609
1984	178138	467774	404280	342644
1985	124506	446880	403759	151207
1986	99176	306647	4071[illegible]	131320
1987	14336	243218	167919	167027
1988	54767	376856	166874	71823
1989	39438	342960	193970	159565

YEAR	FRG	NETHERLANDS	NORWAY	ITALY
1981	702253	172964	310164	271489
1982	615407	212186	347463	176785
1983	798461	231758	182036	255888
1984	627538	134265	93081	147839
1985	850505	72707	78704	63315
1986	818650	193363	88315	33242
1987	341319	59300	62264	312989
1988	521156	59232	52589	144887
1989	430845	88814	32710	327202

YEAR	SPAIN	UK	USA	JAPAN
1981	779619	212696	360136	8399831
1982	557012	434599	215746	8162915
1983	500706	496835	380899	6670317
1984	510825	306984	146702	8972974
1985	387276	177327	117679	8763957
1986	335573	92781	132659	7498721
1987	324541	194231	164326	5707898
1988	161584	59975	10765	4040199
1989	230906	102393	4078	5364600

YEAR	KOREA
1981	929180
1982	1400525
1983	1538592
1984	1618993
1985	2539993
1986	3459775
1987	2090960
1988	3174494
1989	3101566

APPENDIX F. PRODUCTIVITY MEASURES

This appendix is divided into two parts. Part one contains labor productivity as measured in manhours per ship by country. Equations 3.1, 3.2, and 3.3, in Chapter III, were used to formulate this data. Summary totals for Northern Europe, Southern Europe, and European overall are also shown.

Part two of this appendix contains material productivity as measured in metric tons of steel per ship. Equations 3.4, 3.5, and 3.6, in Chapter III, were used to formulate this data. Summary totals for Northern Europe, Southern Europe, and European overall are also shown.

PART ONE

YEAR	Bel Hrs	Den Hrs	Fin Hrs	Fra hrs
1981	637557	840444	957409	956335
1982	742411	847250	921468	904995
1983	940190	1050860	1155697	1084835
1984	1174778	1358077	1307091	1296765
1985	1352548	1601329	1504969	1540360
1986	1084682	1278442	1160416	1282827
1987	968758	1043518	1035527	1161539
1988	1226446	1211288	1160732	1418316
1989	1279325	1322679	1091917	1523569

YEAR	Ger Hrs	Net Hrs	Nor Hrs	NE Hrs
1981	730978	834688	727859	812181
1982	698251	808354	698853	803083
1983	835276	1016820	871951	993661
1984	1075780	1331325	1056976	1228684
1985	1249357	1550780	1222704	1431721
1986	984712	1179635	1058582	1147042
1987	836859	1040173	880451	995260
1988	985150	1296772	1035200	1190557
1989	1064836	1352683	1093586	1246942

YEAR	It Hrs	Span Hrs	UK Hrs	SE Hrs
1981	1007144	1213444	1168563	1129717
1982	984169	1210718	1162081	1118989
1983	1147520	1710188	1504014	1453907
1984	1439766	2147540	1880415	1822573
1985	1647355	2482927	2159406	2096562
1986	1331947	1932528	1922592	1729022
1987	1173297	1700912	1819137	1564448
1988	1410539	1896753	2080867	1796053
1989	1421661	1918417	2133905	1824661

YEAR	EU Hrs	US Hrs	Jpn Hrs
1981	907442	1350967	756265
1982	897855	1012206	846300
1983	1131734	1084231	973963
1984	1406850	1170578	1178194
1985	1631173	1322601	1415975
1986	1321635	1144731	973527
1987	1166016	1100286	859034
1988	1372205	1243404	830774
1989	1420257	1160887	777980

PART TWO

YEAR	Bel Tons	Den Tons	Fin Tons	Fra Tons
1981	77997.6	86345.1	77066.2	78951.6
1982	53250.9	53877.4	52790.5	51456.0
1983	51602.4	53204.9	55986.9	51140.2
1984	54529.1	54529.1	56833.1	53445.7
1985	54062.9	52780.1	56618.6	52959.6
1986	43287.0	44408.5	44873.5	43396.6
1987	39114.1	41344.2	42945.3	40807.3
1988	49609.8	52282.8	53670.8	50540.0
1989	52063.5	59812.5	57154.1	56650.6

YEAR	Ger Tons	Net Tons	Nor tons	NE Tons
1981	72317.1	83550.7	88415.1	80663.3
1982	49375.5	50325.1	62949.6	53432.1
1983	46808.7	49371.7	59075.8	52455.8
1984	49209.2	52404.6	51403.2	53193.4
1985	48962.6	53322.3	51556.7	52894.7
1986	39771.8	42013.9	46963.5	43530.6
1987	35706.4	37781.5	46897.9	40656.6
1988	44841.4	47474.0	53083.6	50214.6
1989	50929.4	54032.3	55191.8	55119.1

YEAR	It Tons	Spa Tons	UK Tons	SE Tons
1981	74616.1	72317.1	61033.6	69322.2
1982	49778.0	51311.8	51168.5	50752.7
1983	47988.7	51293.4	54387.2	51223.1
1984	51732.7	53445.7	54529.1	53235.8
1985	58977.7	53690.1	49904.2	54190.6
1986	42325.1	38177.4	45711.1	42071.2
1987	38952.4	39774.2	44464.6	41063.7
1988	50330.3	49008.5	52395.7	50578.1
1989	53919.0	53249.2	57666.7	54944.9

YEAR	EU Tons	US Tons	Jpn Tons
1981	77260.9	74345.6	62305.3
1982	52628.3	56012.0	52374.2
1983	52086.0	56711.2	49254.5
1984	53206.1	63752.5	46014.6
1985	53283.4	71838.1	46616.5
1986	43092.8	76975.5	42742.7
1987	40778.8	71274.4	40105.7
1988	50323.6	66021.6	43048.7
1989	55066.9	59784.9	49044.8

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